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ORIGINAL PAPERS

SOME FUNDAMENTAL PRINCIPLES GOVERNING THE CORROSION OF A FIRE CLAY REFRACTORY BY A GLASS[1]

BY ROBERT B. SOSMAN

In requesting a paper on this subject the organizers of the symposium placed no limits on the degree of fundamentality, either upwards or downwards. I am therefore taking the liberty of beginning at the farthest limit of generality that our present knowledge of physical and chemical science permits. It is useful occasionally thus to review the principles upon which permanent progress must be founded, even though no new and striking additions are to be recorded.

Entropy

At the bottom of all the activity we see about us, including among the rest the reactions that take place in a glass-pot or tank, is the principle of *entropy*. Hearers and readers sometimes shy at the word, because it is not a word with which they have become familiar in daily life. But the idea is, in fact, simple. It is only that heat will not, of its own accord, flow up-hill. No furnace-builder ever expects the inside of his furnace to get hotter by the flow of heat inward through the walls from the atmosphere, though there is nothing in the principle of the Conservation of Energy which would make such a happening unlikely.

[1] Received Feb. 17, 1925. Presented at the Annual Meeting of the AMERICAN CERAMIC SOCIETY, Columbus, Ohio, Feb. 1925. (Joint Meeting of Glass and Refractories Divisions.)

In more general terms, the principle is a statement of the observed fact that the universe as we know it is going full-tilt toward some far-off but invisible dead level. Entropy is the quantitative measure of its downward progress. It might equally well be called "run-down-ness" (Tolman) or "degree of degradation."

Energy

The other great principle underlying our glass-pot reactions is the one incidentally referred to above, that of the Conservation of Energy, according to which an invisible something called *energy* remains constant in amount though continually changing its form of manifestation.

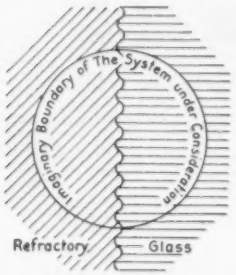

FIG. 1.—Boundary of the system under consideration.

But how apply these principles to the corrosion of a glass-pot? First by setting boundaries to a *system* within which the reactions which interest us are occurring. The system studied may include the whole furnace and pot; or it may be only a tiny volume of material at the boundary of pot and glass, as in Fig. 1. The only limitation to its size is that it shall contain a reasonable number of atoms, say some thousands of millions—its mass would even then be far less than a millionth of a milligram. In the chosen system and the surroundings with which it interacts, taken as a whole, we know there must be a net increase in entropy whenever anything happens.

Zeta

This does not yet enable us to predict very definitely what will happen *within* the imaginary boundary of the chosen system of Fig. 1. Energy may flow in or out across the boundary, and so we must find a quantity involving both energy and entropy, which will tell us what goes on inside. Such a quantity is the *zeta*.[1] So long as any reaction can occur within our chosen system which if it occurred at a constant temperature and pressure would cause a *decrease* in zeta, just so long will things continue to happen in the system. When the possible change in zeta becomes zero, visible changes cease and the system is *in equilibrium*.

Now a refractory which is in equilibrium with a glass at a given temperature will last forever so far as chemical corrosion is concerned,

[1] Called by G. N. Lewis the "free energy" and by other writers a "thermodynamic potential." So important a quantity should have a short and easily remembered name, however, hence I propose to use *zeta*, the name of the Greek letter which J. Willard Gibbs, who laid the foundations of chemical thermodynamics, employed to represent the quantity.

obviously a very desirable state of affairs, especially in a glass tank. The study of the conditions and the values of zeta which lead to equilibrium is therefore of the first importance.

The picture I am trying to present is that of a ceaseless striving after equilibrium at every point where equilibrium has not already been attained. If the refractory in Fig. 1 is not in equilibrium with the glass, then changes leading toward equilibrium are going to take place in both refractory and glass. The case is not essentially different from that of the cup of coffee which we had for breakfast. A cup of hot coffee with a spoonful of sugar in the bottom is a system which is not in equilibrium. The dissolving of the sugar is a process accompanied by a decrease in the zeta of the system. Hence the sugar immediately begins to dissolve.

It may fairly be asked at this point whether we have gained anything by thus restating the case. Why not say simply that sugar is soluble in water? If we expected never to be interested in any other case then there would be no gain in using what seems a more abstruse form of statement. But there are hundreds of ceramic reactions in which we are all interested, each of which would be a single unrelated problem if considered in the obvious way as a case of specific solubility of A in B, but which will fit together into a systematic body of facts from which many further deductions can be drawn, so soon as we regard them from the more general standpoint of the dependence of reactions upon zeta.

Phases and Their Properties

Let us look more closely into the details of the system shown in Fig. 1. We find that it consists of several *phases*, each of which is homogeneous, so far as the microscope can discern. There is a liquid phase, the molten glass. There are also two or more crystalline phases formed from the material of the refractory.

Each of these phases has a set of characteristic properties, by which it may be recognized, no matter where or in what masses it may be found. Among these characteristic properties are the entropy per gram, the energy per gram, and consequently the zeta per gram. We cannot know with exactness the *absolute* values of these properties, but we can know very precisely their *differences* from one substance or condition to another, and these differences are all we really need, just as in measuring temperature we arbitrarily select a zero and proceed to measure the departures from that zero.

A convenient assumption for entropy and energy is to call their values for each chemical element zero at 0°C and 1 atmosphere pressure. This fixes the values of entropy, energy and zeta for every substance at every temperature and pressure, for we need to know only the heat-changes in

passing from the chemical elements over to any specified compound or mixture under any specified conditions.

This will indicate the great importance to ceramics of a knowledge of specific heats a nd heat-changes (heats of reaction, heats of formation, heats of fusion). Their importance is far beyond their practical usefulness in calculations on ceramic processes, for fuel is used so inefficiently—I speak now from the standpoint of physics and chemistry, not engineering—in the firing of ceramic products, that we might guess at the specific heat or assume that all specific heats are the same, with accuracy enough for many practical purposes. The real usefulness of accurate heat data is in giving us general values for zeta. Once supplied with a good set of tables of zeta for various substances used in ceramics, we would have the data with which to answer many a question which can now be answered only after expensive practical trials.

The Third Law

Though it is a little aside from my principal theme, I should like, in passing, to remark upon the importance to ceramic science of a new law of entropy which some have considered important enough to call the "Third Law of Thermodynamics." It states that the entropy-change at the absolute zero of temperature is zero in an isothermal process involving only solids (and possibly liquids.) This principle, which has been demonstrated by means of measurements extending down to within 20° of absolute zero, makes it possible to integrate curves of specific heats ranging up from very low temperatures, and to obtain values of zeta up to very high temperatures with a minimum of high-temperature experimentation. Science thus offers the paradoxical spectacle of an investigator using liquid hydrogen and liquid air to determine constants for use in kilns and blast-furnaces, a thing obviously absurd to the nontechnical man, as absurd as the notion that yellow fever can be eliminated by devoting one's time to killing mosquitoes. And yet, as everyone knows, the Panama Canal was dug with fly-swatters and oil-cans, after the unaided steam-shovel had failed.

The Phase Rule

Data on the zetas of many elements and inorganic compounds have already been assembled, but the ceramic oxides and compounds are lagging behind in this regard. Meanwhile, we must look out for another important—indeed necessary—set of facts which must precede the determining of zeta. I refer to the identification of the possible phases which can occur in the system under consideration. These facts, together with others which might be calculated from the zeta tables if we had them complete, are usually assembled into the *phase-rule diagram* of the system of substances with which we are concerned.

The same principle of decreasing zeta which has already been referred to also enables us to predict with certainty the number of phases which can be in equilibrium under given conditions, when we know the number of chemical components of which the system is made. This important generalization is the *Phase Rule.*

Application to the Alumina-Silica Refractory

Let us assume for convenience of discussion that the refractory consists essentially of alumina and silica, in about the proportion of one formula-weight of Al_2O_3 to two of SiO_2. Originally in the form of a colloidal, suspended, or finely divided hydrous silicate such as kaolinite, the substance of the refractory has been dried and fired, so that it has already started on its way toward the state of equilibrium corresponding to the temperature of the kiln or the furnace. What that state of equilibrium is may be seen from the phase-rule diagram worked out by Bowen and Greig, and presented before this SOCIETY a year ago.[1] (See Fig. 2.)

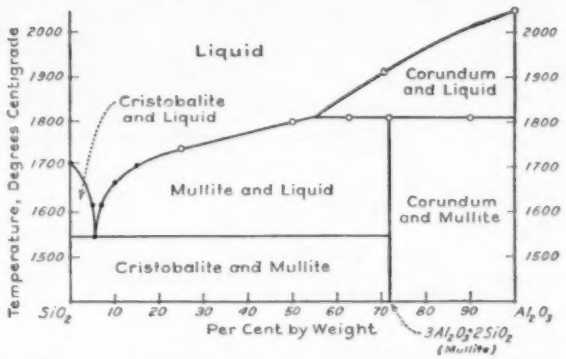

FIG. 2.—Temperature-concentration diagram of the chemical system $SiO_2||Al_2O_3$, according to Bowen and Greig. Weight percentages.

The Phase Rule tells us that $P+F=C+2$. P is the number of phases, F is the number of arbitrarily determinable variables, and C is the number of components. Since the compositions of the phases in this system can be completely described in terms of the two oxides, SiO_2 and Al_2O_3, the number of components, C, is 2. Therefore $P + F = 4$.

What are the conditions determining P and F in the wall of a glass tank? In the first place, we are working under the constant pressure of one atmosphere, which arbitrarily fixes the value of one variable. The temperature also is constant, at say 1350°C, which fixes another variable. The number of phases in equilibrium, then, can be 2, but not more.

Figures 2 and 3 show what these two phases may be. (Figure 3 has been recalculated to molecular percentages from Fig. 2, which is the diagram by Bowen and Greig.) Pure dehydrated kaolinite contains alumina and

[1] N. L. Bowen and J. W. Greig, "The System: Al_2O_3–SiO_2," *Jour. Amer. Ceram. Soc.*, **7** [4], 238–254 (1924).

silica in the proportion 1:2, represented in Fig. 3 by the line *RR*. The final state of equilibrium of the wall at 1350° is therefore represented by the point *W*. It will be a crystalline mixture of tridymite, which is the stable form of pure silica at 1350°, and mullite, which is a compound of the formula $3Al_2O_3.2SiO_2$. There will be no liquid present and no other compound, provided nothing but SiO_2 and Al_2O_3 are present in the refractory.

The Glass

Let us assume for definiteness of discussion that the glass is an ordinary soda-lime glass of the molecular composition $Na_2O:CaO:6SiO_2$. This is an example of a 3-component system, hence $P + F = 5$. If, as before, the pressure is set at 1 atmosphere and the temperature at 1350°C, there may be 3 phases in equilibrium but not more.

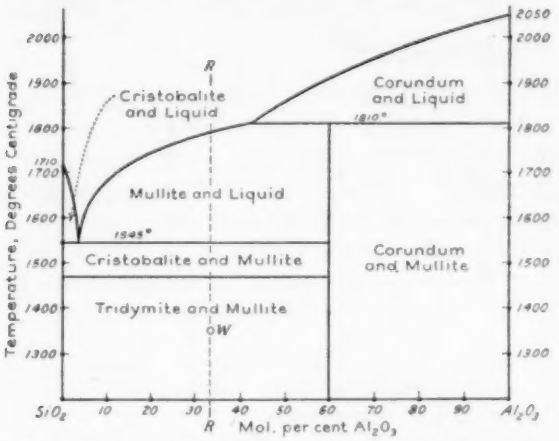

FIG. 3.—Temperature-concentration diagram of the chemical system $SiO_2||Al_2O_3$, with concentration expressed in molecular percentages.

No complete investigation of this chemical system has been made, but some information is available on the siliceous side of it, which is the one in which we are interested. The phase-rule diagram of the system $SiO_2||Na_2SiO_3$ has just been published,[1] and that of $SiO_2||CaO$ has been fairly well known for some time.[2] From the form of these two diagrams it is highly probable that the state of equilibrium for the mixture $Na_2O:CaO:6SiO_2$ at 1350° is a single liquid phase, the molten glass, with no crystalline phases. This is also rendered highly probable, though not necessarily proved, by the fact that it is feasible in practice to manufacture the glass at this temperature.

The System of Refractory and Glass

Consider again the system represented in Fig. 1, consisting of a small portion of glass and a small portion of tank wall, inclosed within an im-

[1] G. W. Morey and N. L. Bowen, "The Binary System Sodium Metasilicate-Silica," *J. Phys. Chem.*, **28**, 1167–1179 (1924).

[2] G. A. Rankin and F. E. Wright, "The Ternary System $CaO–Al_2O_3–SiO_2$," *Amer. J. Sci.*, **39**, 1–79 (1915).

aginary sphere whose position is indicated by the circle in the figure. We have to deal now with a four-component chemical system, the system $SiO_2||Al_2O_3||CaO||Na_2O$. Unfortunately its phase-rule diagram is known only in the most fragmentary way, but some general statements can be made, nevertheless.

$P + F$ is now equal to 6. At the arbitrary pressure and temperature already adopted, the value of P may therefore be 4, that is, four phases can coexist in equilibrium, if no arbitrary limitation is set on the composition of the phases. Since it is unlikely that there will be two immiscible liquid silicates containing all three of the basic oxides, the four phases,

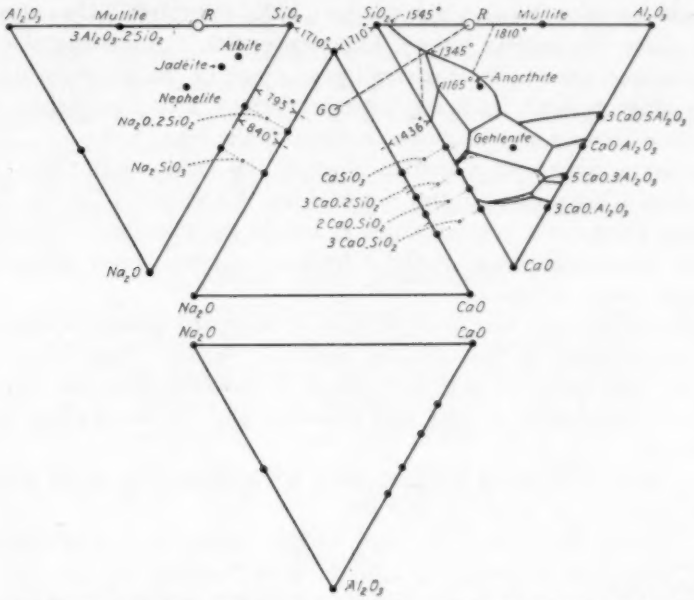

FIG. 4.—Outline of compositions in the four 3-component systems which bound the 4-component system $SiO_2||Al_2O_3||CaO||Na_2O$.

if so many are present, will probably consist of one liquid (molten glass) and three crystalline phases.

Graphical representation of equilibrium diagrams becomes more difficult as the number of components increases. With two components, we could get along with a plane diagram as in Figs. 2 and 3. With three components, we can represent all possible compositions by the now familiar plane triangular diagram, leaving the third dimension perpendicular to the plane to represent temperature or pressure. When we have four components, all possible compositions can be represented by points within an equilateral tetrahedron in space, but no coördinates remain in which to

represent temperature or pressure. We are then driven to the procedure of using a series of tetrahedrons, each representing compositions at one temperature and pressure.

The four faces of the tetrahedron still serve to represent the compositions in the four three-component systems which can be made from four components. They are outlined in Fig. 4 for the system $SiO_2||Al_2O_3||CaO||Na_2O$. The composition of the glass is represented by the point *G*, that of the refractory by *R*, and compositions produced by the mixing of the two would lie along a line within the tetrahedron, extending from *G* to *R*.

As already noted, the state of equilibrium for a three-component mixture of the composition Na_2O: CaO: $6SiO_2$ at 1350° is probably that of a single liquid phase, the molten glass. Experience with aluminous glasses indicates, further, that at least a small percentage of Al_2O_3 can be dissolved in this glass without its being brought thereby into equilibrium with a crystalline phase containing one or more of the four oxides.

The juxtaposition of a molten glass of the composition Na_2O: CaO: $6SiO_2$ and a refractory of the composition Al_2O_3: $2SiO_2$, as in Fig. 1, therefore produces a system which is not in equilibrium. The alumina-bearing crystalline phase of the refractory, mullite, must therefore immediately begin to dissolve.

Whether tridymite also must dissolve to bring the system to equilibrium it is not possible on this general basis to foretell. Experience shows, however, that silica, as well as alumina, is dissolved from the refractory, and the presumption is that this reaction, also, is one leading towards equilibrium.

Thus there is produced a liquid phase whose composition lies within the tetrahedron, on or near the line *RG*.

The ultimate state of equilibrium of the imaginary system represented by Fig. 1 cannot be predicted exactly, both because we lack the necessary phase-rule data, and also because we have not defined just how much glass and refractory the arbitrary boundary incloses. Possibly, at 1350° the whole would become liquid. Or it might be that before the portion of refractory included within Fig. 1 was completely dissolved, new crystalline phases would appear. Phases which might possibly result from attainment of equilibrium at 1350° within the boundaries of Fig. 1 are: (1) aluminous liquid glass, (2) alumina (corundum), (3) mullite ($3Al_2O_3.2SiO_2$), (4) tridymite (SiO_2), (5) sodium disilicate ($Na_2O.2SiO_2$), (6) pseudo-wollastonite ($CaSiO_3$), or (7) a lime-soda feldspar in the series between albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$). Not more than four of these could exist together, and the aluminous glass would almost certainly be one of the four. At all events, equilibrium would ultimately be reached and visible changes within the system of Fig. 1 would cease.

In actual fact, changes never quite cease, for the boundaries of this system are wholly arbitrary. To the right of the figure, particularly, is a mass of glass which is very large compared with the mass of Fig. 1, and this glass is no longer in equilibrium with the glass inside Fig. 1, whose composition has been changed by the reaction with the refractory. Diffusion must therefore occur across the boundary of the figure, into the pot or tank of glass, even though there should be no mixing by convection, and since this upsets the equilibrium within Fig. 1, further reaction must occur between the glass and the crystalline phases.

Nevertheless, the imaginary closed system of Fig. 1 is to a limited extent realized in practice, because of the slowness of diffusion and convection. If the phases which are the natural product of the reactions within this system can be provided beforehand in manufacturing the refractory, equilibrium at the boundary will be by that much nearer to attainment and corrosion should be correspondingly reduced. It ought to be possible to select more intelligently a refractory for a particular temperature and a particular glass, when detailed data on the stable phases and the values of zeta in such a system as $SiO_2 || Al_2O_3 || CaO || Na_2O$ shall have become available.

Rate Versus Equilibrium

If I seem to have devoted a considerable share of my time to the statement of these fundamental principles without bringing forward the data necessary for a detailed and quantitative application of them, it is because I wish to emphasize the distinction between the idea of equilibrium and another even more important idea, that of the *rate of reaction*. The distinction might appear so obvious as to require no emphasizing, were it not for the fact that authors of articles and discussions so often fail to keep the distinction clear. The possibility of confusion is shown by the very fact that we often use the same word for both ideas. We speak of the "solubility" of sodium chloride in water, for instance, meaning the concentration of the saturated solution *in equilibrium* with the salt, while we speak of the "solubility" of quartz in hydrofluoric acid of various strengths, meaning in this case the *reaction-rate* of the quartz with the acid.

An understanding of the equilibrium toward which reactions are moving must come first. There cannot be a race without a goal. But the race itself may be a long and complicated proceeding, and some of its features must next be considered.

Rates of Reaction

The principles governing rates of reaction are not so well understood as those governing equilibrium. Some of the phenomena of reaction-rates appear to have no rhyme or reason whatever, but the proportion of such is gradually being reduced by the progress of experiment and theory.

We know with certainty that the occurrence or non-occurrence of a reaction depends upon whether or not the zeta-change associated with the reaction is a *decrease* (page 192). It appears also logically necessary that the magnitude of the zeta-change should be related in some way to the rate, but the form of the relation is not known. We do know that they are not proportional, for some reactions with a large zeta-change go very slowly, while others with a small zeta-change go rapidly. The same contrast is found in many mechanical systems.

A piece of wet clay, for instance, can be deformed by the pressure of a finger, while the green brick made from it will stand a fairly heavy load without deforming. Although the force is so much greater in the latter case, the rate of response to it is practically nothing, because the absence of water so greatly increases the frictional resistance to motion of the particles.

In spite of the lack of quantitative data, we can find certain qualitative principles which will apply to the case of the glass and the refractory.

Diffusion

A fact of basic importance is that reactions between atoms or between molecules can only occur when they approach within distances of the same order of magnitude as their own size. There is no evidence to show that a given atom has any attracting or repelling effect upon a second atom which is so far away that hundreds or thousands of others intervene. If they meet, it is by virtue of their own wanderlust.

It is this wanderlust of atoms, families of atoms (molecules), and even tribes of atoms, that we usually call by the name *diffusion*. It is obviously a very important quantity when we are dealing, as in the present case, with a reaction at the boundary between a solid and a liquid. If the alumina and silica which enter the boundary zone from the refractory, and the lime and soda which enter from the main mass of glass, all diffuse very slowly, then equilibrium will soon be very closely approached in the zone of liquid glass next to the refractory, and activity will accordingly nearly cease, if the liquid is not carried away from the surface mechanically.

Surface Reaction-Speed

A second important factor in the rate of reaction between solid and liquid is the actual speed of combination between atoms at the active surface. The high temperature in the glass tank leads us to expect that this speed will be very great, for speeds of reaction are sometimes more than doubled by an increase of temperature of only 10°. On the other hand the slow rate at which silica and the siliceous alkali feldspars change from the crystalline to the amorphous state suggests caution in making assumptions about speeds of interaction of siliceous phases even at high temperatures. But, on the whole, it appears likely that the speed of interaction at the

surface is enough greater than the speed at which the products diffuse, that diffusion will be the controlling factor. The slower the rate of diffusion, the slower the rate of attack by the glass.

Factors in Speed of Diffusion

The next question, then, is: What controls the speed of diffusion?

Most important of all is the nature of the medium through which diffusion occurs. It is most rapid in gases. In liquids it is immensely slower, while in solids it is several hundred times slower still and is usually not measurable at all at ordinary temperatures. Bowen[1] has shown that the rate of inter-diffusion of silicates of the character typified by diopside ($CaSiO_3.MgSiO_3$) and albite-anorthite mixtures ($NaAlSi_3O_8$ and $CaAl_2Si_2O_8$) at 1500°C is of the same order of magnitude as the rate of diffusion of glycerin in propyl alcohol at room temperature.

In liquids of similar character and at the same temperature, the rate at which a given substance diffuses is inversely proportional to the *viscosity*. Now the viscosity of a glass increases rapidly with its silica content. The dissolving of silica from the refractory produces a more siliceous glass near the surface of contact, and therefore strongly depresses the rate of diffusion, thereby diminishing the rate of attack.

There is one kind of diffusion which deserves to be considered here because it is so much more rapid than the usual slow diffusion through a liquid medium. I refer to phenomena such as the passage of hydrogen and helium through vitreous silica (quartz glass) at a high temperature. This may become so rapid as to take on the character of an actual flow of gas, as if through capillary pores, yet it is not a flow of this kind, as is shown by its failure to agree with the laws based upon kinetic theory.

There is some evidence that rapid diffusion such as this may take place through a molten glass. It is perhaps encouraged by the presence of halogen compounds, water, and in general those substances which the petrologist calls "mineralizers" and to which he assigns an important role in the formation of crystalline silicates in a molten magma. If such diffusion does occur, it is not a matter of indifference to the refractory manufacturer what fining agents the glass-maker adds to his glass, even though they are minute in amount and cannot be shown to have any direct chemical action on the refractory. These considerations are still hypothetical, however, and must not be taken as a statement of fact established experimentally under glass-manufacturing conditions.

Mechanical Factors

Mention should be made of the mechanical factors in the rate of corrosion, though these are more difficult to define in general terms than the

[1] N. L. Bowen, "Diffusion in Silicate Melts," *J. Geol.*, **29**, 295–317 (1921).

physico-chemical factors. The first is the factor of flow or circulation in the glass. In the considerations which have preceded, we have assumed, for simplicity, that the liquid glass stands still. This is never true. There is convection due to differences of density and to the movements of gas bubbles, and in the tank there is progressive flow forward. These movements of the glass come to the aid of diffusion by carrying away or mixing the glass near the walls, thus making the concentration gradient steeper and increasing the rate of diffusion.

Although I do not know of any study which has been made of the character of flow in a glass tank, it may be worth while to distinguish two logically different cases, namely, steady flow and turbulent flow. Steady flow is the type which takes place through a smooth straight pipe or out of a properly designed orifice or nozzle. Turbulent flow is the more usual kind, occurring in a rough pipe which has sharp bends.

Steady flow yields a uniform and predictable gradient of pressures in the stream, and correspondingly a uniform concentration gradient which produces a minimum of disturbance in the natural or stationary rate of diffusion. Turbulent flow, on the contrary, produces thorough mixing and gives the maximum aid to diffusion, thereby increasing the corrosion.

Viscosity is the important factor in determining the character of flow. The greater the viscosity, the slower the response to whatever forces are causing circulation

This has a secondary consequence, also, in controlling the amount of turbulent flow, because the steady type can be converted into the turbulent by an increase of speed.

For these two mechanical reasons, then, high viscosity in the glass next to the wall is desirable: first, it decreases the speed of flow of whatever kind, and second, it reduces the proportion of turbulence.

The direction of circulation of the glass in a small, uniformly heated pot, as shown experimentally by Coad-Pryor,[1] depends upon whether the density of the original glass is raised or lowered by the initial attack on the wall. In a tank, on the contrary, it is reasonable to suppose that this factor is of smaller importance, and that the differences of density which cause circulation are due principally to the cooling of the glass at the walls.

Another mechanical factor is the texture of the refractory. A porous refractory, which permits the liquid to penetrate and attack the bonding material between the grains, would appear logically to be less resistant to corrosion than a dense refractory which offers a much smaller surface for interaction between the liquid glass and the solid phases. This factor has often been emphasized in discussions of pot and tank corrosion. The point has been brought out that rapid but *uniform* corrosion may be pref-

[1] E. A. Coad-Pryor, "Notes on Pot Attack," *J. Soc. Glass Tech.*, **2**, 285–287 (1918).

erable to corrosion which is slow but which produces stones with such material as is set free from the refractory. This is a consideration of very different kind from those which form the basis of the present paper.

Summary

Emphasis is placed on the important distinction between *equilibrium* and *rate of reaction*. The occurrence of any reaction is determined by the value of the quantitative property called *zeta*, which can be found by means of measurements of latent and specific heats. This quantity also determines the number of phases present at equilibrium and the way in which the equilibrium changes with temperature. The number and the character of these phases depend upon the composition of the chemical system made up of glass and refractory; the problem in the corrosion of a pot or tank by a lime-soda glass, for example, is a problem of the crystalline phases in equilibrium at a certain temperature with an aluminous liquid phase in the four-component system $SiO_2||Al_2O_3||CaO||Na_2O$.

The rate at which progress is made toward the attainment of this equilibrium is determined mainly by the rate of *diffusion*, which in turn depends upon the viscosity of the liquid glass. Mechanical factors, such as steady or turbulent flow, must also be considered.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON

Discussion

ALBERT B. PECK: Frankly, I do not feel that I am enough of a physical chemist or that my experience with glass has been sufficient to entitle me to make any detailed criticism or discussion of Dr. Sosman's excellent presentation of the principles involved. But I do feel that occasion should be taken again to call to the attention of refractory and glass manufacturers the fact that much of the data accumulated by members of the staff of the Geophysical Laboratory can be made of great use in practical manufacture. Most of the information cannot be taken over bodily because the manufacturer is limited in many ways, especially with regard to the purity of materials used, because of which crystalline phases may appear at points other than where they appear when pure materials are used. This does not mean, however, that the fundamental principles involved cannot be used to advantage in many cases.

Dr. Sosman's mention of mineralizers under which are included dissolved halogens, water, boron compounds, and others, as an aid to diffusion in glass is common knowledge to the mineralogist, but I wonder how many glass manufacturers have thought of it in that way. As I said in the beginning, I am not very familiar with glass, but if my memory is right in this matter, halogen compounds, especially fluorides, are an important con-

stituent of many opal glasses and I think Dr. Washburn has obtained SiF_4 from opal glass by his special method of evacuating the furnace while the glass is molten. Also as I recall it, opal glasses are very fluid glasses, and are not easy on pots or tank walls. If this is true it seems worth while to give some consideration to the relation of these mineralizers and diffusion.

Dr. Sosman also mentions the matter of the texture of the refractory, referring especially to its porosity. There is another point regarding texture. I once had occasion to examine microscopically a pot wall for the effect of the glass upon it. The body was one which had a coarse grog with a fine binder. The corrosion had been decidedly uneven and the microscopic thin section showed very plainly that the glass had rapidly penetrated into the areas of the fine binder. At some points it was apparent that two such tongues of glass had nearly met behind a good sized grog particle and in a short time a stone would have been thrown off as a result. Stones themselves are not desirable but the further point is that if that body had been more uniform in texture it might have lasted longer.

Another suggestion which may be away from the point is that the most successful pot or tank block would seem to be what may be termed a one component body. It may not be composed of one crystalline compound alone, but should have a very large percentage of that compound. With this would need to be combined a great resistance to solution. Careful study would show what would be a satisfactory compound in regard to the latter factor. How to form that compound or a body carrying a high percentage of it, into a pot or tank block might prove to be a large order but it probably will be done sometime just as many things which once seemed impossible are common now.

PRESENT AND FUTURE WALLS FOR USE AGAINST MOLTEN GLASS[1]

By Robert J. Montgomery

ABSTRACT

The early glass pot was made of German clay, which, because of its lack of refractoriness, was later mixed with Missouri fire clay. The war made it necessary to substitute American bond clay for the German which was still used. The batch drifted from one of high silica, such as that obtained with all German clay, to one of comparatively low silica without its being realized. While German clay is now available, it is recognized to be unnecessary.

Aside from going back to a high silica pot and the use of porcelain pots for special glasses, little progress has been made in pot composition. The pot of the future will probably be of clay, but of white firing clays, carefully selected. The structure will be uniform, rather fine grained with greater refractoriness, depending upon greater freedom from impurities. Its chemical composition will be suited to the composition of the glass melted and the temperature of the furnace. The density will be under control and will depend upon the fluidity of the glass at the temperature of melting.

Introduction

Way back in 1910 at Ohio State, Prof. Purdy gave me a clay in the senior laboratory to identify for some commercial use. It was a refractory clay of some description and among other tests, I made a small pot and melted some cullet in it. Apparently there was little or no attack of the glass on the clay so I reported that the sample was a glass pot clay. Although I was very much in doubt at the time, I am now convinced that my conclusion was correct. A clay which may be formed into a pot and will not be readily attacked by molten glass is a glass pot clay.

While the subject of this paper could be taken to include both glass pots and tank blocks, the data and experience used for this discussion is based largely on glass pots. I believe the fundamental principles involved are the same for both.

History

H. L. Dixon has very well outlined the early history of the present pot.[2] First it was German clay, which, when used alone, starts to overfire between cones 15 and 20 and fuses at cones 27 to 28.

A more refractory batch was required and the Missouri fire clay came into its own, being mixed with the German clay. This fire clay is more refractory than the German clay. At cone 20 it shows but little overfire and has a fusion point of cone 32.

Soon after this the World War started and the importation of German clay was cut off. There was a grand scramble for substitutes and it was

[1] Recd. Dec. 22, 1924. Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, February, 1925. (Glass and Refractories Divisions.)

[2] *Bull. Amer. Ceram. Soc.*, **3** [11], 416 (1924).

this period, 1914 to 1918, that forced a lot of progressive work on the subject. As early as 1912 some of the pot manufacturers were working on the German clay substitute so no very serious interference with production resulted when the foreign supply was cut off. Much to the surprise of many of the old timers, business went on about the same as usual.

Two new pots were introduced, one the high silica batch by C. H. Kerr, then of the Pittsburgh Plate Glass Co., and the other the porcelain pot by A. V. Bleininger, then of the Bureau of Standards. After the war a reaction set in and there has been a considerable demand for German clay, although many pot manufacturers are still using their new batches.

The slowness of the development of the glass pot industry has been largely due to three things:

(1) The pot is sort of a side issue from the main project of manufacturing glass and very few glass house superintendents go beyond insisting upon good pots in the most general of terms. This is true whether the pot house is at the glass plant or not.

(2) The time required to experiment with batches is very long. It has often been the practice not to use pots under a year in age, although this is now cut to as low as three months. At best it takes an average of six months to get the clay from the pit to the furnace and with a furnace life of one month to a year as in the case of a tank block, very few changes can be made in a period of two or three years. Furnace conditions so often make results of tests doubtful and unless there is a decided failure, it is difficult to draw conclusions.

(3) The cost of the clay and labor is small compared to the value of the glass which may be spoiled if a manufacturer finds himself with a lot of pots on hand which seemed good during an experimental period but which fail to give good results when introduced into regular operation. Glass manufacturers are very slow in taking up anything new in pot composition as so much is at stake.

Present Status

There are four types of glass pots on the market:

1. German clay blended with American clay
2. American clays blended. No German clay
3. American clays blended, high silica batch
4. Porcelain type using American clays.

Good pots have been made of all of these types, which brings out the significant fact that all refractory clays are glass pot clays and that my laboratory report, calling an unknown fire clay a glass pot clay back in 1910 was correct. The highly plastic German bond clay is a glass pot clay and the flint fire clay, raw or fired, which has little or no plasticity, is

a glass pot clay. It is not the individual clays used, but the properties of the blended combinations, which are important.

Raw Materials

A study of the American and English specifications for glass house refractories[1] shows how hopeless a task it is to classify the properties of glass resisting refractories in terms of softening points, porosity, shrinkage, etc. In general terms the American specification calls for cone 29 as the minimum for any clay used and the English specification calls for cone 28 to 29 for Grade 3 bond clay. The Gross Almerode clay will hardly pass cone 28. I have tested samples giving about cone $27\frac{1}{2}$. One thing is apparent and that is, specifications cannot be written which will bar any refractory clay which is reasonably free from impurities such as iron, 2.5% Fe_2O_3 being the maximum given by the English specification. As a matter of fact it is not the individual clays which are subjected to operating conditions but it is the mixture of raw materials so compounded as to give a batch which has the desired properties. In other words, in picking out raw materials its effect upon the batch should be studied more than its characteristics when studied by itself.

A case in point is the use of substitutes for German clay. Attempts were made to find an exact duplicate in an American clay. It is now known for a fact that the need of German clay was more mental than actual and by proper blending of American clays, satisfactory results in the finished batch can be obtained.

It is fairly well understood that a glass pot clay should be of the refractory type, having a fusion point of cone 29 or above, although some of the German clays and German clay substitutes have a fusion point as low as cone 27. The kaolins, flint clays and ball clays used should show no tendency to overfire at cone 20 while the bond clays, whether German or American, usually show considerable bloating at cone 20 but none at cone 15. The fire clay may or may not show overfire at cone 20, but in case it does it should be very slight.

The chemical properties are not so definite except as they show the typical difference between the various clays. The kaolin will have a high alumina and low silica content, as 38% Al_2O_3 and 46% SiO_2 with the iron content as low as 0.5%. This will grade to a sandy clay like the Gross Almerode with 71 to 73% SiO_2, 15 to 19% Al_2O_3, with iron at 1.5%. In some of the fire clays and impure ball clays the iron will run as high as 2.5%.

Proportioning the Pot Batch

Little need be said on the physical properties of the pot up to the time it goes to the furnace. The pot manufacturer has learned to so proportion his raw clay and grog to give the desired plasticity, drying shrinkage and strength in the green state. From 40 to 50% raw clay is used, the balance

[1] *Bull. Amer. Ceram. Soc.*, **2** [3], 29 (1923); *Jour. Soc. Glass Tech.*, **3**, 4 (1919).

being non-plastic material. Of the raw clay 8 to 12% is generally a good bond clay firing to a dense body at a low temperature and having a long vitrification range. The balance of the raw clay portion is made up of fire clay or kaolin. This is where the Missouri fire clays have been largely used. Flint clay is seldom, if ever, used raw. It has no plasticity, so it is only of value as a grog, which should be ground fine to avoid causing stones.

The non-plastic portion or 50 to 60%, may include pot shell, feldspar, silica, alumina, whiteware bisque, calcined flint clay and fired fire clay, pot shell usually being about 10 to 25% of the total batch when this material is available.

More exact proportions cannot be laid down because much depends upon the properties of each clay used and the properties desired in the pot. Papers by Clark and Forsyth,[1] Grafton,[2] Brownlee and Gorton,[3] give a very good idea of the care necessary to make a good pot after it is proportioned.

The result of all the foregoing is a pot in good physical condition delivered to the glass plant for use. It will stand heating up in a rather crude pot arch to an uncertain temperature, can be transferred to a melting furnace without cracking, will stand up in the furnace and give reasonably good results when melting soda-lime or low lead glass at normal melting temperatures.

Resistance to Destruction

Whether it be tank block or glass pot, from this point on we are no longer interested in the plasticity and bonding power of the clay, the coarseness of the batch to allow drying, arching and transferring to the furnace or the heating of a tank furnace. What we have is a wall for use against molten glass at melting temperatures. If we want to study this wall as it is in service we must look to the pot shell or broken up pot or block after it comes from the furnace.

Composition

Analyses of pot shell are not very plentiful in ceramic literature and apparently it is not considered to be of importance. The work by Bleininger[4] on optical glass pots, and Fuller[5] on pot mixtures, does not give any information on glass pot composition as far as the per cents of the various oxides go. Still, the Pittsburgh Plate Glass Co. has taken out two patents (1,217,953 and 1,278,164) calling for the addition of 8 to 30% free silica as sand to the batch, and English[6] after testing a mixture of 90% natural sillimanite with 10% ball clay states that his figures conclusively prove that glasses attack

[1] *Jour. Amer. Ceram. Soc.*, **5**, 146 (1922).
[2] *Ibid.*, **3**, 653 (1920).
[3] *Ibid.*, **4**, 97 (1921).
[4] *Ibid.*, **1**, 25 (1918).
[5] *Ibid.*, **3**, 569 (1920).
[6] *Jour. Soc. Glass Tech.*, **7**, 248 (1923).

a well-fired clay crucible much more rapidly than they attack a similar crucible made from sillimanite mixture.

I am listing thirteen analyses showing a silica content from 56.45% to 78.6% and an alumina content from 16.9% to 38.8%. It is possible to get practically any working properties desired, any shrinkage and porosity of the pot shell combined with the necessary refractoriness and use approximately the limits here given.

TABLE I

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO-CaO	Alkali
1	56.45	38.83	1.39	1.56	0.74	1.28
2	60.86	35.40	1.09	....	.54	2.02
3	62.60	33.00	3.02	0.41	.87	0.46
4	62.71	32.85	2.95	....	.51	1.00
5	63.80	33.25	1.74	....	.10	1.17
6	64.17	31.46	1.86	....	trace	2.51
7	66.68	29.12	1.55	1.10	0.77	0.75
8	66.92	28.71	0.94	....	.72	2.59
9	69.53	26.65	.81	....	.48	2.53
10	70.37	26.92	.91	....	.42	1.16
11	75.50	21.64	1.80	....	.48	0.65
12	77.00	19.90	1.72	1.05	.53	.46
13	78.60	16.90	0.70	2.2	.90	.50

Numbers 1, 3, 4, 5, 6, 7, and 11, are pots made by five of the best known pot firms in the country. Numbers 2, 8, 9, and 10 are of the porcelain type, as may be guessed by the rather high alkali content. Number 12 is a foreign pot. Number 13 is Gross Almerode clay with the combined water left out, as given by Fuller in his study of bond clays.[1]

According to our best knowledge, there was a time in this country when Gross Almerode clay comprised the entire pot, part being fired and the remainder raw clay. I have therefore listed the analysis of this clay with the other pot batches and we find that it is a very high silica batch. Evidently a high silica batch is not new. When the German clay content of the batch was cut down, the batches drifted to ones of lower silica content probably because the Missouri fire clays used had a lower silica content.

In three analyses given by Evers[2] (see Table II) pots used in 1868 and 1887 are compared with the 1921 pot. There is a 5% lowering of the silica content with a corresponding increase in alumina. Evers recognizes this as a definite change but is not sure that it is an improvement.

A glance at the eutectic curve between silica and alumina shows that any proportion of these two materials will be refractory enough to withstand glass melting temperatures if pure raw materials are used. The

[1] *Jour. Amer. Ceram. Soc.*, **4**, 904 (1921).

[2] *Jour. Soc Glass Tech.*, **5** [20], 331 (1921).

eutectic point of 94.5% silica will fuse at 1545°C or 2813°F.[1] With 70% to 80% silica in the batch, the melting point would be at least 100°F above this. It would seem foolish to say that the ultimate composition is not important.

TABLE II[2]

	1868	1887	1921
SiO_2	71.1	70.0	65.3
Al_2O_3	25.0	24.5	28.5
Fe_2O_3	2.0	2.0	2.2
TiO_2	1.1	1.1	1.1
MgO-CaO	0.5	0.7	0.7
Alkali	.8	1.2	1.4
	100.5	99.5	99.2

Structure

Next comes the structure. In use, a pot is very porous as it comes from the arch and has a water absorption of about 30%, almost porous enough for a water filter. After two or three days in the furnace it reaches more or less an equilibrium, that is, little more change will take place in the pot, due to the temperature of operation. The fluxes have melted and combined, the reactions between alumina, silica, alkali, iron, lime, etc., have gone nearly to completion, as nearly as can be, hindered as it is by the size of grain of the material.

We still have a porous mass. The degree of density will depend upon the composition of the batch and the temperature to which it is exposed. The porosity of a pot, after going eleven melts, showed 13.6% at the rim and 21.7% at the center of the bottom. A pot of the same composition after twenty-seven melts showed 5.5% porosity at the extreme edge of the rim and 24.0% at the center of the bottom.

Table III shows how the density of the shell can be controlled by increasing the amount of flux in the batch and by that means decreasing the amount of open pore space and still maintain the necessary refractoriness.

TABLE III

Percent porosity	Fire clay pot 1	Fire clay pot 2	Porcelain pot 1	Porcelain pot 2
Rim	9.28	13.70	2.61	1.13
Belt	10.92	18.25	2.39	1.85
Knuckle	14.21	13.99	1.82	1.82
Bottom	17.45	19.08	6.37	3.52

It is undoubtedly true that heavy lead glass of better quality can be made in a pot of low porosity like the porcelain one given above than in the old porous fire clay pot, disregarding any ordinary difference in the ultimate analysis.

[1] Bowen and Greig, *Jour. Amer. Ceram. Soc.*, **7**, 243 (1924).

[2] Analyses given by Evers calculated to the fired basis.

Firing

The effect of firing a rather refractory porcelain pot for six hours at 2600°F before filling in is shown below (Table IV).

TABLE IV

Position	Per cent porosity
Rim	5.55
Belt	5.90
Knuckle	5.83
Bottom	5.85

In this case all parts of the pot would be equally resistant to penetration.

We see that it is possible to make a pot of the required refractoriness with a variation in absorption or porosity from about 2% up to 25% and maintain almost any silica-alumina ratio desired. The present day pots are within the limits as indicated, although I believe that in most cases the properties obtained are more or less accidental and are not deliberately controlled by the pot manufacturer.

The Pot of the Future

Glass manufacturing is changing. The melting temperature is higher and the variety of glasses made increases every day. The pot has not changed to any extent since the Missouri clay replaced a large portion of German clay. The porcelain pot is not used outside of a few plants making special glasses and, as now made, it is not suited to general purpose needs.

Several new raw materials for pots have been suggested but it is not likely that any material will replace clay for some time to come. The clay pot can be improved and that is the problem now before the pot maker and glass maker alike.

As far as I can see, there are only two important things to consider when the clay wall comes in contact with the molten glass at furnace temperature. First is the chemical composition of the wall and second is the physical structure. When these two points are determined for a given glass and melting temperature, the body must be so compounded that the batch may be worked into a pot or block and successfully brought to furnace temperature.

Influence of the Glass

But all glasses are not alike and all furnaces are not run at the same temperature, so it is not at all likely that all glass can be melted in the same pot. There is no reason to believe that a high silica pot will be best for soda lime glass, lead glass, opal glass, colored glass, etc., or that a high alumina pot is best for all. The problem then, is to classify glasses not only as to composition but as to furnace temperature and to establish the best silica-alumina ratio for each class, having the physical structure of

the clay body under control at the same time. If the density of the pot is not considered in conjunction with the chemical composition, the work would be of little value.

A very fluid barium glass will penetrate a pot with a porosity of 20% almost like water penetrates a sponge. There is no need for the glass to attack the pot. The glass will run through it.

This extreme case illustrates the point. The corrosiveness of a glass depends largely upon its fluidity or viscosity. A pot wall which is penetrated by the glass does not last long.

Prefiring

It has often been suggested that prefiring the pot to a high temperature before use would give the desired density. While this is certainly true, considerable could be done in proportioning the pot batch so it would mature at the normal furnace temperature, giving the desired density.

Pure Pot Materials

Pure kaolins, china clays, ball clays, and flint clays low in iron, should make up the batch and the fluxes used should be added with direct intent. There is no reason why alkali should be the only flux used to control the bond. Some other fluxes might be found to fill up the holes in the skeleton kaolinite body, which would resist the chemical action and penetration of the glass far more than an alkali. The fire clays now used introduce a heterogeneous flux of impurities under no control. Herbert Insley, in his study of glass refractories,[1] has given us considerable to think about on the subject of the flux. A flux easily dissolved in the glass allows the grog to float out into the pot.

Low Coefficients

The coefficient of expansion of the batch should be studied so that with a more dense, uniform structure, the risk of cracking, due to temperature changes in heating or in use, would be reduced. The coefficient of expansion of the flux would also be important.

The pot of the future, I believe, is one manufactured under as carefully controlled conditions as the spark plug or pyrometer tube. The raw materials are white firing and carefully selected. The structure is uniform, rather fine-grained, the refractoriness depends upon the chemical composition and not upon the coarseness of the grind. In use, it presents a wall suited in chemical composition to the temperature of the furnace and to the glass which comes in contact with it. Not only is the silica-alumina ratio correct but the fluxes are carefully selected as well. The density will be under control and will depend upon the fluidity of the glass at the temperature of melting.

Bausch and Lomb Optical Co.
Rochester, N. Y.

[1] *Jour. Amer. Ceram. Soc.*, **7**, 583 (1924).

Discussion[1]

W. W. OAKLEY:[2] In the opinion of the writer this paper brings out very effectively the progress of development in the proportioning of pot clay mixes to date and makes a rational prediction of its probable course in the future. There are a few points that I want to discuss from the viewpoint of the glass manufacturer rather than the viewpoint of the ceramic engineer interested not only in the development of pot mixes but in the rapidity of this development.

Among the first reasons given by the author for the slowness of development is his statement made that "Very few glass house superintendents go beyond insisting upon good pots in the most general terms." There appears to be an extremely wide range of meaning to this term "good pots," and whenever the term is used it almost seems to be necessary to consider the viewpoint of the man who uses it. The pot manufacturer's definition of a good pot might be one that is easy to dry, one that will stand considerable jarring stress and when used will give a long life. The glass manufacturer making non-corrosive, easily plained glass will likewise agree with the pot manufacturer that these pots are good. The glass manufacturer making a highly corrosive glass or the manufacturer making a glass plaining up with difficulty except at the highest temperature may find these pots short-lived and condemn them, and lastly the glass manufacturer making an intermediate glass product which is later converted into a different article in automatic machines might be troubled with a stone loss, far more important to him than anything else because it might upset the operation of the automatic machines on a later operation. Consequently, particular care should be used in criticizing pots of one kind or another, because such criticism is seldom forgotten by the hearer and is apt to do an injustice to the person responsible for the pots, whether it be an outside manufacturer or a department of the glass works in question.

On page 207 the statement is made that the need of a Gross Almèrode clay is more mental than actual. While this, I think, is essentially true, if time and the necessary money is to be expended in developing the proper blending of American clays, I think that most pot manufacturers will agree with me in the statement that the use of German Gross Almerode clay resulted in a far more fool-proof mix. What I mean is that fewer mistakes and bad results would be obtained by using the German clay than would result from the commercial manufacture of pots from blended American clays and this statement applies not only to pot life but to the ability of the pot to resist jarring stress, improper firing and still be accompanied by the production of good glass of various kinds.

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[1] Submitted Feb. 27, 1925.

[2] Corning Glass Works.

The statement is made that it is possible to get practically any working properties desired, and I assume physical characteristics, within the limits of the silica-alumina ratios given in Table I. It has seemed to the writer that this whole problem of clay composition could not be approached from either the viewpoint of physical properties or chemical composition alone as the pot manufacturer generally has to contend with the question of building a pot for use with a glass of some general composition. A pot of one composition would stand up satisfactorily and give good glass with one kind of glass where it might be absolutely worthless with another. I have found it to be impossible when even considering one plant to keep a definite glass in a pot made for it, and, of course, the commercial pot manufacturer can do nothing in this respect.

Regarding the relation between the silica-alumina ratio and the question of corrosion, we have recently had an instance where two ceramic engineers worked on the same problem but at different times and different places. The problem was to secure a satisfactory tank block for use with a highly corrosive lime glass. The methods and apparatus used were the same and the test furnace in each case was of the same design. In the first case the most satisfactory block composition was found to have a silica-alumina ratio of less than 1.8. The second man on the same problem worked in the other direction and just as definitely proved that the high silica block was more satisfactory, finally arriving at the conclusion that this silica-alumina ratio should be 2.75. It is such conditions as this that tend to perplex the glass manufacturer.

In considering a study of the pot wall after it has reached a point in the furnace where it is not subject to much change, I think it is necessary to consider the type failure before one is justified in thinking about the effect of chemical composition of it. Certainly failures resulting from drying and heating strains or possibly due to poor dimensions and, likewise, a failure due simply to overheating or overrunning due to the furnace man's neglect are not worthy of analysis by chemical methods. To draw conclusions from the chemical analysis of the shell it is necessary to first modify the conclusions by eliminating failures which are due to anything but corrosion. Likewise, in considering corrosion failures it is necessary to consider temperatures, the rate at which glass was being melted and even the possibility of badly mixed pot materials.

In speaking of the pot being equally resistant all over to penetration, there is some question in my mind as to whether this will result in uniform corrosion. In a plant I know of the pot bottoms are practically perfect, but the side walls are not good due to vertical cuts which may be due to filling methods or stress at some time between the making and the filling period. Yet, I have seen these same pots with certain glasses fail uniformly at seven days by bottom penetration with absolutely no trouble

on the side walls. With other glasses no corrosion of the bottom at all occurred. Consequently, we again have the importance of the kind of glass being considered in considering resistance to penetration.

When the pot manufacturer is able to maintain a technical control which will result in a uniform run of pots which will fail owing to glass corrosion, I think close consideration of the chemistry of the mixture will furnish wonderful results. However, until we are able to mix clay and deliver it to the pot maker so that it is of uniform chemical composition with grog of uniform sizing and when our pot making methods are so refined that failures due to voids and improper knitting and drying are gone we can do more to improve our pots and clays along these lines than by considering chemical composition as of paramount importance. Also, I am inclined to think that the last sentence presents a large problem for the commercial plant.

CORNING GLASS WORKS
CORNING, N. Y.

THE USE OF MUFFLE TUNNEL KILNS FOR THE "ARCHING" OF PLATE GLASS POTS[1]

By P. d'H. Dressler and L. T. Strommer

ABSTRACT

Muffle tunnel kilns have now been in use for five years for the purpose of preheating or "arching" plate glass pots. The use of this type of equipment has brought about substantial savings in labor and fuel, and has increased the average life of the pots by approximately 21%.

Introduction

Pots are Expensive

One of the heavy items of expense in the manufacture of plate glass is that of the pots in which the glass is melted. The size of these clay containers is very great, varying from circular pots 4 feet 6 inches in diameter and 34 inches high, weighing over one ton, up to oval pots of the same width and height, 6 feet long, weighing 3850 pounds. These pots have thicknesses in some cases up to 10 inches. They are built up by laborious methods from expensive, prepared, washed clays by skilled workmen. It takes many days to build up a pot and, in most factories, months to dry satisfactorily. The investment in a sound dry pot ready for use including the material and labor which enter into its manufacture and the cost of the expensive floor space occupied for such a long period usually amounts to from $50 to $75.

Pots Vary in Quality

It is the experience of every plate glass factory that the life of these pots is extremely variable. Not only do the pots from different batches of raw materials made at different times show marked variations but also great differences are found between the behavior of pots made from the same batch at the same time and used, apparently, under identical conditions. Some pots have to be withdrawn from use after only a very few melts due to the development of cracks and leaks. Others will reach forty or even more melts before they become so worn around the ring that the crane can no longer hold them, without having developed any leaks at all. Some pots from the very first melt persistently cast up "stones," others give perfectly clear glass throughout their whole life.

Factors Which Affect Life of Pot

There are, of course, innumerable factors which will affect the life and service of a pot. The quality of the raw materials, the nature of the batch, the skill of the maker, the drying process, the preheating to the furnace temperature or the "arching," the skill of the melting furnace tender

[1] Recd. Dec., 1924. This paper was presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, Feb., 1925. (Glass and Refractories Divisions.)

in controlling the heats and avoiding "burning" of the pots, the care of the crane man in avoiding breakage due to knocking or squeezing the pots, are all factors which must be reckoned with.

The Old Way of Arching Pots

The kiln or "arch" used in most plate glass factories for preheating the pots up to the temperature necessary to prepare them for the melting furnace is of the crudest type. In most cases it consists simply of a rectangular box of fire brick in which five pots are set and provided with only one fire hole. The temperature is usually raised to 1800° in about five days when the pots are removed as required and set in the furnace. The control of these arches is crude and due to irregularities of treatment not infrequently pots are cracked in them during their initial heating and cannot be used at all. It is, therefore, apparent that in substituting arching equipment which would give complete control from start to finish and eliminate the possibility of sudden or irregular heating at all stages of the firing, one of the important unknowns among all the factors bearing upon the life of the pots would be removed and this would simplify the study of the requirements to decrease pot costs per square foot of plate glass manufactured.

Car Tunnel Kiln for "Arching"

Some five years ago the Pittsburgh Plate Glass Company, after a careful study of all possible types of equipment, decided to install a muffle tunnel kiln which type they felt would most completely give them the absolute evenness and control they desired. This tunnel kiln has been in operation since August, 1919. Since that time three others have been installed and put into operation, the most recent one at the plant of the Ford Motor Company, Glassmere, Pa. These installations have uniformly given the very best of service. Up to this time nothing has appeared in the literature of the glass or refractories industries regarding them and it appears to the authors that some of the details of the operation and of the results obtained would be interesting at this Colloquium of the Glass and Refractories Divisions.

The Car Tunnel Kiln

The design of a tunnel kiln for arching glass pots involved a number of problems not met with in any other ceramic industry. The essence of most tunnel kilns is that they shall operate continuously with cars placed and taken out at regular intervals. In the glass plant the pots are needed only for 18 hours out of the 24, during which the casting is being carried on, and only as required to replace the pots removed from service. Sometimes three or more pots will be required in quick succession. At other times there will be no call for any pots at all for 48 hours. Furthermore from the very nature of the operation such a kiln has no cooling zone

and provisions have to be made to withdraw the pots at the highest temperature.

Manifestly, if regularity and evenness in preheating are desired, it will be fatal to push in four fresh cars at the entrance end, in an interval of fifteen minutes, if that number of cars is suddenly required from the exit end, since this would involve a sudden jump in temperature of the pots in the danger periods of the heating cycle. The tunnel kiln, therefore, must have a reserve of hot pots in the furnace zone which can be withdrawn without moving forward the whole train at more than the regular operating speed.

If the pots are withdrawn from the hottest section of the kiln for a space of, for instance, 20 feet back from the door, it is apparent that the floor and the tracks, being no longer covered by the car bottoms, are exposed to the full radiation of the crown. This introduces the double danger of destroying the floor by overheating it and subsequently, when the cars

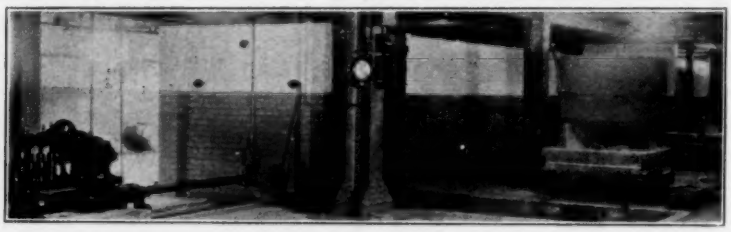


FIG. 1.—Entrance end of pot arching tunnel kiln showing method of loading pots on the cars and the hydraulic propeller.

are gradually pushed up over the hot floor, of overheating these also by means of the stored heat in the latter. Then there is the difficulty of providing a reasonably tight door at the exit end which will permit of pots being withdrawn at about 2000°, the temperature required in most installations.

The "Dummy" Car at Exit End

Figure 2 shows the exit end of a tunnel kiln in which these difficulties have been successfully encountered. The door is composed of a steel frame lined with insulating brick, operated by means of an air cylinder. Between the door and the hottest portion of the kiln is what is known as a "dummy car" or a short car bearing a brick structure closely conforming to the side walls and arch of the kiln, which serves the double purpose of preventing the full heat of the kiln from reaching the door and acting as a reservoir of heat to prevent the last pot in the kiln from being cooled by proximity to the door. This "dummy car" is connected to a long rack by means of which it can be withdrawn from the kiln across the transfer car and into a small fire brick house. By means of an automatic device,

when the "dummy car" is pushed by means of the rack into contact with one of the kiln cars, it couples itself to the latter and the two cars are then moved as one by means of the rack. The operation of the kiln, then, is as follows:

Let us suppose that the full length of the kiln is occupied by a train of cars loaded with pots and that the "dummy car" is directly inside the exit door. When a pot is required, the exit door is opened and, by means of the rack, the pot-bearing car and the "dummy" are simultaneously withdrawn. The transfer car is in place and the dummy car passes over it. As it does so the coupling device is automatically tripped leaving the pot-bearing

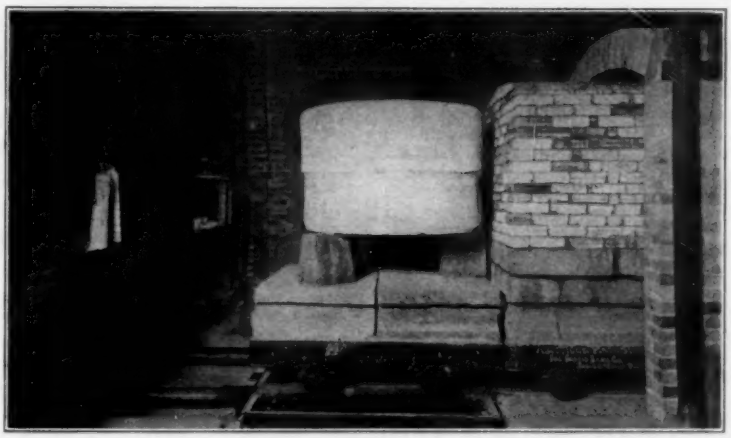


FIG. 2.—Exit end of pot arching kiln. On the left hand side is seen the steel door of the tunnel kiln. On either side of the door are the natural gas burners projecting their flames down the tunnel kiln combustion chambers. To the right is the brick structure used to house the "dummy car" during the time it is withdrawn from the tunnel kiln. The "dummy car" is shown coupled to a kiln car bearing a pot just before the coupling device is automatically tripped, leaving the car, bearing the pot, on the transfer. The next operation is to move the transfer under the casting ball crane and remove the pot.

car on the transfer while the "dummy car" passes into its house. The exit door of the kiln is then closed and the transfer car moved out beneath the furnace hall crane which picks off the hot pot and transfers it to one of the furnaces. The kiln car is then moved onto the return track where it is allowed to cool before a fresh dry pot is set upon it, while the transfer car is moved back to the position directly in front of the exit door of the kiln. The latter is raised and, by means of the rack, the "dummy car" is returned into the kiln. If necessary it can be pushed in far enough to pull a second or a third car immediately. When the kiln propeller is

started up on taking out the first pot, a fourth pot can be reached within a few minutes.

Protection of Kiln Floor

It will be seen that when this process is completed a considerable length of kiln floor is exposed to the full heat. In order to prevent damage it is composed of a steel plate, air cooled on the under side and covered with a thin layer of insulating material on the upper side. The latter prevents direct heating of the metal and at the same time has so low a heat capacity that after it has become heated by exposure to the full radiation from the arch, no trouble on the under sides of incoming cars is caused by it.[1]

Length of Kiln

The lengths of the tunnel kilns vary according to the desired production and the size of the pots. The shortest of the kilns is 151 feet and the longest 170 feet. The least number of pots in a kiln is 26 and the greatest 33. The time of arching in most installations is from 84 to 96 hours. In one of them, however, it has been found possible to run on a 54-hour schedule. In this case the batch is of a sandy open nature and will stand more rapid heating. The temperature at the delivery end varies from 1850 to 2000° on different installations.

In two of the plants where tunnel kilns have been built these supply the full requirement of arched pots. In the other two the kilns were designed to have a capacity of less than the maximum requirement and in these plants part of the pots are being supplied, during the peak load periods, from the old type of pot arching furnaces.

The Economies of Car Tunnel Kiln for Arching

After five years of operation it is possible to state that the tunnel kilns have shown, in comparison with the old arches, three distinct sources of economy, *viz.*: labor, fuel and increased life of pots.

Labor

In all of the installations the hot pots are delivered beneath the casting hall crane runway. The pot is picked off the car by means of the same carrier that is used to transfer the pots to and from the furnaces and the casting table. The special wheeled carriage and the large number of men needed to reach and handle the pots in the arches are no longer required. One man is able to take care of all the operation of the tunnel and on natural gas no attention at all is required during the intervals in which casting is not taking place.

Fuel

The average amount of fuel per pot required in the intermittent arches has been given to the au-

[1] The construction and method of operation of the exit end of the pot arching tunnel kilns are protected by patents.

thors as 22,000 cubic feet of natural gas. The fuel consumption in the different tunnels varies according to the rate of operation, the lowest average fuel consumption being 4600 cubic feet and the highest 8000 cubic feet per pot. The fuel saving is, therefore, from 63% to 79% and at 35 cents per M cubic feet for natural gas this amounts to from $4.90 to $6.10 per pot.

Pot Life

Pots cease to be of any use when, owing to the development of cracks or leaks, they will no longer hold glass, or when they start to throw up so many stones that the glass melted in them is not satisfactory. As already stated there are very many factors in addition to the "arching" which have an influence upon the service of the pots, and it is apparent that any improvement in the method of "arching" will show its effect much more in the early life of the pots than in the later, since by the time a pot has been used 20 to 40 times so many influences have had an effect upon it.

Furthermore, to make any comparison between the results of the different methods of "arching" upon the life of the pots it is useless to compare the life of pots "arched" in tunnel kilns with the life of pots "arched" in the old fashioned manner in the previous month or the previous year. The only satisfactory way is to compare the life of the same batch of pots passing through the arches and the tunnel kiln simultaneously and being used in the same melting furnaces at the same time. In the case of the two plants in which the production of pots is divided between the tunnel kilns and the arches, it has been possible to make this comparison. Very careful and complete records were made which are set forth in the tables.

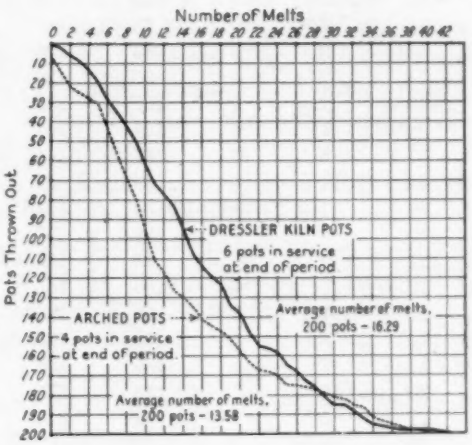

Number of Melts
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Pots Thrown Out
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
DRESSLER KILN POTS
6 pots in service at end of period
Average number of melts, 200 pots - 16.29
ARCHED POTS
4 pots in service at end of period
Average number of melts, 200 pots - 13.58

FIG. 3.—Cumulative curve showing life of pots arched in intermittent arches and in tunnel kiln.

In case of plant No. 1 a very careful check was made upon the life of the first 200 pots taken from the tunnel kiln and of 200 pots simultaneously arched through the old intermittent arches. The pots were put into service during a period of six weeks and their life was followed through for the following six weeks. At the time that the observations were concluded all of the pots had been discarded except six from the tunnel kiln and four from the arches. The full data are shown in the following table and are summarized in the accompanying curves (see Fig. 3):

COMPARATIVE LIFE OF POTS IN KILNS AND IN ARCHES

Life of pots in melts	Number of pots scrapped		Cumulative number scrapped		Total melts		In service at end of period	
	Kiln	Arches	Kiln	Arches	Kiln	Arches	Kiln	Arches
0	1	7	1	7	0	0		
1	1	7	2	14	1	7		
2	4	8	6	22	8	16		
3	3	3	9	25	9	9		
4	5	3	14	28	20	12		
5	6	3	20	31	30	15		
6	9	13	29	44	54	78		
7	6	13	35	57	42	91		
8	8	11	43	68	64	88		
9	7	12	50	80	63	108		
10	12	16	62	96	120	160		
11	10	15	72	111	110	165		
12	5	6	77	117	60	72		
13	6	9	83	126	78	117		
14	12	4	95	130	168	56		
15	12	4	107	134	180	60		
16	7	7	114	141	112	112		
17	5	3	119	144	85	51		
18	4	3	123	147	72	54		
19	11	4	134	151	209	76		
20	4	6	138	157	80	120		
21	10	6	148	163	210	126		
22	7	4	155	167	154	88		
23	1	1	156	168	23	23		
24	2	2	158	170	48	48		
25	7	5	165	175	175	125		
26	3	0	168	175	78	0		
27	5	1	173	176	135	27		
28	3	1	176	177	84	28		
29	5	2	181	179	145	58	1	
30	4	2	185	181	120	60	3	1
31	0	1	185	182	0	31		
32	3	3	188	185	96	96		
33	4	1	192	186	132	33	1	1
34	3	5	195	191	102	170	1	1
35	1	2	196	193	35	70		
36	1	2	197	195	36	72		
37	1	1	198	196	37	37		
38	0	2	198	198	0	76		
39	0	0	198	198	0	0		
40	0	2	198	200	0	80		1
41	1		199		41			
42	1		200		42			
Totals	200	200			3258	2715	6[1]	4[1]
Av. melts					16.29	13.58		

[1] Those pots still in service at the end of this period of observation were considered as having been thrown out at that time and melt.

The curves are plotted in such a way as to show the cumulative number of pots thrown out at successive melts. The area between the two curves represents the total difference of life obtained by the different methods of arching. It will be noted that there were very markedly less pots thrown out in the early melts of the tunnel kiln pots than of the arched pots. Seven arched pots were found cracked when removed from the arches and gave no service at all. One tunnel kiln pot is shown as having given no service. This pot was one of the first withdrawn from the tunnel kiln. It emerged sound but was broken by the crane-man who was not yet familiar with the lifting of the pots off the tunnel kiln cars.

The greatest divergence between the curves occurs around 12 melts. From the tunnel kiln pots 77 were thrown out with 12 or less melts as against 117 from the arched pots. From this point forward the tunnel kiln pots naturally show a higher rate of loss than the arched pots since there are more of them left and the various influences of age and service are beginning to tell. After 18 melts the curves approach each other rapidly. By this time all influence of the arching has been eliminated and at the higher melts the curves are practically identical.

The total number of melts from the tunnel kiln pots was 3258 with an average of 16.29 per pot and from the arched pots 2716 with an average of 13.58 per pot. If the tunnel kiln pots had shown the same average life as the arched pots exactly 40 more would have been required to give the same number of melts. Assuming a cost of $60.00 per pot this means that in the first six weeks' operation of the kiln the increase of pot life showed a saving of 40 × $60, or $2400.00.

In case of plant No. 2 a record was taken of all the pots removed from the tunnel kiln and the arches for the first five months of the former's operation, and subsequently the history of all these pots was followed through until every one of them had been thrown out of use. The results are shown in the following table:

COMPARATIVE LIFE OF POTS IN KILN AND ARCHES

	Pots arched		Total melts		Average per pot	
	Kiln	Arches	Kiln	Arches	Kiln	Arches
1st month	117	106	1785	1196	15.26	11.28
2nd month	93	94	1317	1327	14.16	14.12
3rd month	123	59	2197	993	17.85	16.83
4th month	132	50	2264	740	17.15	14.80
5th month	111	56	1952	718	17.59	12.82
Totals	576	365	9515	4974		
Average melts per pot for whole period					16.52	13.63

The difference in life here is fractionally higher than in the case of plant No. 1. Unfortunately, sufficiently detailed data are not available to draw up the same kind of a curve. However, if the tunnel kiln pots had shown the same life as the arched pots, to make 9515 melts, 697 pots would have

been required. The difference between this figure and 576, or 121 pots, is the number saved by the use of the tunnel kiln for arching. At $60.00 per pot this amounts to $7260.00. It will be noted that when this kiln was started up the pot requirements were divided more or less evenly between the tunnel and the intermittent arches but gradually, as the results obtained were checked, the proportion of pots from the tunnel kiln was increased. At the present time the tunnel kiln is supplying from 75 to 85% of all the pots used in a seven-furnace plant.

The figures above, quoted from the operation of these two plants, are taken over a sufficient period of time to justify the claim that the use of the muffle tunnel kiln with its exact control and freedom from sudden changes can and does bring about a substantial improvement in the services obtained from the pots amounting in the cases quoted to an average increase of life of approximately 21%.

CLEVELAND, OHIO

Discussion

C. E. FULTON:[1] This paper covering the use of the muffle tunnel kiln for the arching of plate glass pots is very interesting and the results which we have obtained with one of these kilns in general check with the conclusions that have been drawn.

However, there is one improvement in the modern plate glass factory which throws a different light upon the economy claimed for the tunnel kiln in labor saving. Instead of having a gang of men to take a hot pot from the arch, it is now the practice to have an electrically operated truck fitted with tongs with which one man can go into a pot arch and remove a hot pot which is to be set into the furnace. This man is one of the regular casting hall organization and the work of removing a pot from the pot arch is only one of his many duties. The fact that the hot pot coming from the tunnel kiln is handled by the regular crane man does not eliminate the man above referred to from the casting hall organization, and while the amount of labor is somewhat less, there is no saving for the company except the cost of operating the electric truck.

It is stated that the fuel consumption per pot is from 4600 to 8000 cubic feet of natural gas when arched in the muffle tunnel kiln. In the manufacture of plate glass on a large scale, it is essential that there be no interruptions in the casting hall work which would interfere with production. It is therefore necessary whenever a defective pot is thrown out of the furnace, to have another new pot hot and ready to set. For this reason we have found it necessary to build three storage arches, which are kept hot and filled with pots from the tunnel kiln. If the fuel for these auxiliary or storage arches, which we deem necessary, is included with that consumed

[1] Recd. March 8, 1925.

by the tunnel kiln, the average gas consumption per pot is approximately 18,000 cu. ft. The fuel per pot consumed in the regular pot arches shows a great variation according to whether the pots are used as soon as they are heated up to the required temperature, or whether they are permitted to remain in the arch for several days after they have been brought up to temperature. The figure of 22,000 cu. ft. per pot given by Mr. Dressler was an average figure at our plant when we were using a smaller pot than we are at present. Using a large pot weighing approximately 3800 pounds, the gas per pot when arched in the regular pot arches is around 35,000 cu. ft., although one month last year 103 pots were put through the regular arches with an average gas consumption of 18,500 cu. ft. per pot.

Since the installation of the tunnel kiln we have arched 16,297 pots of which 71% were arched in the tunnel kiln and 29% in the regular pot arches. During this time we have had approximately 1% of the pots from the tunnel kiln broken during the arching period, while in the regular pot arches 3% of the pots have been broken. The greater part of the breakage in the tunnel kiln has undoubtedly been due to pots being set which contained some invisible defect caused either in the making or drying. The same thing applies to pots in the pot arches, and in addition some of the breakage in the arches has been due to pots made from experimental batches. No experimental pots are put through the tunnel kilns because when breakage does occur in the tunnel kiln, it is liable to cause serious damage. On two occasions over a period of more than five years a pot breaking in the tunnel kiln has caused damage which necessitated shutting the kiln down for repairs. In the first case the kiln was out of operation for 12 days and in the second case for only 6 days.

We find in general that the life obtained from pots arched in the tunnel kiln averages about 2 melts better than those arched in the regular arches. This checks rather closely with Mr. Dressler's statement of an increase of 20% in life.

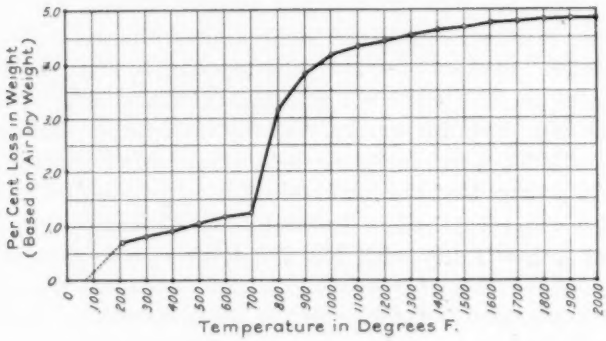
Mr. Dressler states that the ordinary pot arches found in plate glass factories are very crude. This statement is correct, but it might be pointed out that even with this crudeness, very good results have been obtained over a long period of years. This is no doubt due to the fact that the preliminary heating or arching of a plate glass pot is really a very simple operation and if performed with a reasonable degree of intelligence, good results will be obtained.

The ordinary plate glass pot batch contains anywhere from 40–60% of non-plastic material ground to pass an 8- or 10-mesh screen. The amount of volatile matter which is driven off during the arching period seldom exceeds 5% (mostly moisture and water of hydration), and the firing shrinkage taking place during this period approximates .5%. In Fig. 1 is shown the percentage of loss in weight of a typical pot batch when

held at various temperatures until it reached constant weight. This curve shows that 14% of the total loss occurs by the time the pot has been heated to 210°F and that 86% of the total loss has been driven off when a temperature of 1000°F has been reached. Therefore, if reasonable care is exercised up to a temperature of 1100 or 1200°F, no trouble should be experienced.

For the best results in arching, the pot itself should be thoroughly dried when set in the arch, and the arch and stack connected with it should be dry so that there will be sufficient draft to carry off the moisture as it is evaporated. We have found it advisable to store pots in a hot room at a temperature of 135–140°F for approximately 5 days so that when they are set in the arch or tunnel kiln, the free moisture will not exceed .75%. Each individual pot arch is equipped with a recording pyrometer and the rate of heating to be followed marked plainly upon the chart for the guidance of the pot arch fireman. When these precautions are followed, good results are obtained from the ordinary type of pot arch.

Pot arches are not insulated in order to reduce the fuel consumption because the time required for cooling would be increased and thus a larger number of arches would be required.



It used to take months to dry a pot satisfactorily. Pots which formerly took 6–8 months to dry are now being dried successfully on a commercial scale in 8 days by the use of a humidity drier.

In planning a new factory the tunnel kiln method of arching would certainly be used. Where a factory is already equipped with sufficient pot arches the amount of saving in a tunnel kiln is greatly decreased. The production at the Ford City plant has increased to such an extent that we are now considering the installation of a second tunnel kiln.

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THE EFFECT OF RED HEARTS IN FIRE CLAY BRICK[1]

By M. C. Booze[2]

ABSTRACT

Laboratory tests made on two brands of fire clay brick indicate that red hearts, which are normally considered as being detrimental, add to both the hot and cold strength and would not be objectionable except in furnaces operated at a low temperature, and in which spalling is an important item. Results of load, reheating and spalling tests are given, together with porosity and iron oxide determinations. A short discussion of the causes of red hearts is also included.

Introduction

Red hearts, or cores, occur in a rather large percentage of the fire clay brick manufactured and have always been considered objectionable, both by the manufacturers and consumers. Data which have been obtained in this laboratory make it apparent that these objections are unwarranted and the results which are given below are presented in the hope that they will help to clarify the matter.

The chemical and physical phenomena producing this discoloration have been discussed by Orton.[3] Here the conclusion is reached that the color in the center of a brick is made stronger or brighter by the iron present in the clay first being reduced and later reoxidized, while that in the outer portions remains in the oxidized condition from the first. This conclusion is evidently justified, it being well known that more intense colors are produced in firing iron bearing clays by alternate periods of oxidation and reduction than by continuously oxidizing or reducing firings. The reduction at the center, which causes the core, results from carbonaceous matter which is present and which is more difficult to burn out in the interior than at the surface. The condition is aggravated if the brick are wet, since, in this case, the oxidation of the carbonaceous matter is retarded, and by the time the brick have been dried by the kiln gases the latter have approached the temperature at which the iron is reduced by the combustible material in the clay.

The fact that some clays are subject to this discoloration while others are not is explained by differences in iron content, amount and kind of carbonaceous matter present, and relative density of the products.

In the reduced condition the iron is active as a flux and from the results obtained during this investigation it appears that a portion of the iron in the cored brick had been reactive in this way, although it had been suffi-

[1] Presented at the Annual Meeting of the American Ceramic Society, Columbus, Ohio, February, 1925. (Refractories Division.) Received Jan. 2, 1925.

[2] Senior Fellow, Refractories Manufacturers Association Fellowship, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.

[3] "Rôle Played by Iron in the Burning of Clays," *Trans. Amer. Ceram. Soc.*, **5**, 377 (1903).

ciently changed by reoxidation as not to have an appreciable effect upon the refractoriness of the product as tested. These conclusions are based upon the fact that the hot and cold strengths of the cored brick are both noticeably higher than those of the uncored ones.

The Investigation

The brick used for the tests here described were obtained from two different manufacturers. Those in each lot were made from identical mixtures of clays as nearly as was practicable and received the same heat treatment, being fired together. For the purposes of our tests, therefore, the only difference between the brick in one lot was that some of them had typical "red hearts" and others were of the usual color throughout.

The following results were obtained from tests on these samples:

	Brand A Samples with red cores	Uncored samples
Load test, 25 lbs. per sq. in., 1350°C, for 1½ hrs.	First lot 5.56% deformation Second lot 5.68% deformation	First lot 9.23% deformation Second lot 8.00% deformation
Reheating at 1400°C for 5 hours	0.50% expansion	0.85% expansion
Spalling as received	Failed after 5½ dips (average of 3)	Failed after 15 dips (average of 3)
Spalling after reheating	Failed after 2½ dips (average of 3)	Failed after 2 dips (average of 3)
Modulus of rupture—cold	1040 pounds per sq. in.	690 pounds per sq. in.
Porosity	18.4%	20.5%
Fe_2O_3 content	2.89%	2.99%

	Brand B Samples with red cores	Uncored samples
Load test, 25 lbs. per sq. in., 1350°C for 1½ hours	First lot 3.98% deformation Second lot 1.01% deformation	6.12% deformation 4.79% deformation
Reheating at 1400°C for 5 hours	2.03% expansion	1.12% expansion
Spalling after reheating	Failed after 3 dips (average of 4)	Failed after 3½ dips (average of 4)
Modulus of rupture	751 pounds per sq. in. (average of 10)	419 pounds per sq. in. (average of 10)
Porosity as received	27.8%	28.0%

Discussion of Results

Load Tests

In each load test two bricks were tested in one furnace at the same time, one being a cored and one an uncored specimen. In this way any inequalities as to temperature, atmosphere, etc., were removed.

A considerable difference is noticeable between the cored and the uncored brick in these tests, the former deforming less in each case. As previously explained, this is probably due to the strong bond developed by the iron during the period that it was in the reduced state. A similar effect may be obtained by hard firing, although in this event more of the fluxes take part than just the iron oxide.

Reheating Tests All of the brick tested expanded in this test, the expansion being greater on the uncored samples of one lot than those having red hearts, and the reverse being true on those of the second lot.

Except in those cases where the expansion is due to the formation of a vesicular structure, or where it is abnormally high, it has not been found possible to draw any definite conclusions from the results of the reheating test, especially with regard to the behavior in actual service.

The rate of heating appears to be more of a determining factor in many cases than either the composition or the temperature and a slow schedule such as is encountered in the majority of industrial furnaces during the initial heating up of the lining has but little effect in producing permanent expansion.

The reheating test is of considerable value, however, in preparing the brick for the spalling test, and it was largely for this reason that the samples reported on here were refired.

Spalling Tests The results of this test show no appreciable difference between the cored and uncored samples when they have been reheated before spalling. When tested without reheating, the uncored samples of one lot gave appreciably better results than those containing red hearts.

The standard method of test calls for reheating before spalling and from the very large number of tests made in this laboratory it is evident such is the logical procedure. Brick which are made from comparatively poor clays and given a soft firing may show very good results in the spalling test if tested as received, due to the fact that they are not maintained at a high temperature for a sufficiently long time in the test to produce the vitrification which would normally take place in service. This point is illustrated by the results obtained on the "A" brand of brick. In this case reheating the uncored samples had a very great effect upon the spalling test results and evidently produced a much more brittle body than did the red hearts alone.

Cold Strength and Porosity The modulus of rupture is considerably higher on the cored samples of both lots than on the uncored ones. In one case this increase in strength was apparently gained by merely sintering the grains together at the points of contact, as there was no appreciable difference in porosity be-

tween the cored and uncored bodies. In the second case a consolidation of the mass accompanied the increase in strength, the porosity being reduced from 20.5 to 18.4%. This reduction in porosity, however, is small. Differences of this order occur in brick which are, for all practical purposes, made alike.

Iron Content

These determinations, which show a difference in iron content between the cored and uncored parts of an amount less than that which may occur from variations in the clays and errors in the analyses, were made to prove that there was no concentration of iron in the highly discolored portion.

Conclusions

The results of these tests show that instead of being inferior, fire clay brick containing red hearts are, for many purposes, superior to those of equivalent composition, grind, etc., but which do not have the red hearts. The former are stronger, would deform less in service and in all probability would show less shrinkage than those of the usual color. The core affects the brick in much the same way as hard firing, the beneficial results of which are evidenced by the growing demand from consumers for hard-fired products. For low temperature furnaces, where spalling is the major item producing failure, the red hearts would be objectionable.

The cored brick are unsightly in appearance and this has doubtless been the cause for many complaints. The color difference is so marked as to make it appear that there is a concentration of iron in the cored zone, which, as has been shown, is not the case.

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Discussion

G. A. BOLE:[1] Mr. Booze's problem is most interesting to me from the standpoint of fundamental data. Red cores both in fire brick and face brick have been considered a defect, a sort of an indictment of poor firing practice and indeed they do go hand in hand. This phenomenon is quite common in the face brick industry where fire clays containing iron and sulphur are used, with or without much carbon. Mr. Booze, quoting Dr. Orton, suggests that carbon reduction with subsequent oxidation is probably the cause of the red core. I would like to ask Mr. Booze if he has the chemical analysis of the original clay and of the cored and uncored ware.

I am under the impression that the sulphur gases rather than the carbonaceous matter are the principal reducing media in most cases at least, although the actions will overlap in some cases. The carbon will of course retard the oxidation of the sulphur when there is much organic matter present thus aggravating the situation. The idea that sulphur rather than

[1] Superintendent, U. S. Bur. Mines, Ceramic Expt. Station, Columbus, Ohio.

carbon is the culprit comes from the fact that draw trials from a commercial kiln may be perfectly free of black core (having been burned out) and still later a red core will develop. The ware may "remain open" for days thus giving the iron abundant time to reoxidize if no other factor were retarding the oxidation. The sulphur oxidation or "blue smoke" period seems to be where the red core is "burned out," the assumption being that if this period is run through too quickly the reducing sulphur gas, arising from the decomposition of iron sulphur compounds, will not be burned out of the clay soon enough to give the iron a chance to reoxidize before the body "closes up." The sulphur may probably be in the fuel in some cases, being absorbed by the clay, but in most cases at least it is in the clay.

As pointed out by Mr. Booze, a wet bottom holds back the temperature in the bottom of the kiln, thus subjecting the ware to a sudden rise in temperature when it is finally dried out. This explanation holds whether the reduction is due to carbon or sulphur. We have found, however, that large quantities of sulphur gases from the coal are absorbed by the ware in the bottom of a wet kiln and fixed there by chemical combination—very largely with the iron. To just what an extent this is a factor in later developing a red core we do not know. The red core under the microscope appears to be due to a film of a reddish brown iron stain on the clay grains.

In extreme cases of red coring specks of a brilliant red glass will show up when examined under the microscope. These specks, so far as observed, are always in the slag craters caused by the fusion of the ferrous silicate. I have thought of them as iron in colloidal suspension in a glass although we have not made a study of the phenomenon. In cases where the red core is less pronounced this red glass does not generally show up, all the color being due apparently to the stain on the clay grains.

M. C. Booze:[1] Unfortunately, no sulphur determinations were made upon any of the materials or products covered in this paper. As Mr. Bole has pointed out, sulphur from the decomposition of sulphides would produce a reducing action upon other iron compounds in the same way as carbonaceous material. The coring could then be caused by either or a combination of both, according to the amounts which were present. There are some fire clays used which contain a relatively large amount of pyrite, and which, to the writer's best knowledge, do not produce red cored brick. This lack of coring may, of course, be due to a well regulated firing process, or to the fact that the iron is present in particles of comparatively large size.

Whether the reduction is due to carbon or sulphur, the net result should be the same and the data given here showing the effect of the core should hold for either case.

[1] Reply to Mr. Bole's Discussion, by Mr. Booze. Received March 16, 1925.

AN ANALYSIS OF THE SUSPENSION OF ENAMEL BY CLAY IN TERMS OF THE COLLOID THEORY[1]

By Emerson P. Poste[2]

ABSTRACT

A detailed review of the literature on the action of electrolytes and organic matter on clays is given.

The problem of the "setting up" of enamel has held the attention of many investigators. But numerous as the efforts seem to have been the published practical results are very meager. This statement is made with no malice, for the writer has done his share of "floundering" along this line and undertakes the present effort very humbly. What we have been groping for is an idea as to the fundamental principle of the suspending of enamel by clay, with due regard to the action of "vehicles" added in "setting up," and a means of using such findings in the shop.

As we look back we feel that our main weakness may have been in the lack of a definite idea of the mechanism of the process and in the use of a wrong conception of the physical properties of the enamel slip as related to its application to the ware.

Possibly a rather definite hypothesis as to the functioning of clays in processing enamel would be of value. The colloid theory has been profitably applied to clay under other conditions of use, why not to enamels?

An effort has been made by the writer to formulate a definite statement of the colloid theory as applied to the processing of enamel by the wet method. This is based largely on the ideas of others as quoted from the literature. Quite naturally there are differences of opinion on many of the details.

General

As a batch of finely ground enamel with clay and water leaves the mill, it is probably a mixture of non-colloidal enamel and clay particles, colloidal enamel and clay particles, and water with such materials in solution as may have dissolved from the enamel or other materials during grinding.[3] The colloidal matter is probably in the sol form. These statements are on the assumption that no "vehicle" has been included in the mill charge.

The addition of the electrolyte used in "setting up" probably flocculates the colloidal matter forming a gel. If the amount of water is not too excessive to allow the gel and the solid matter of the system to form

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb. 1925. (Enamel Division.)

[2] Director of Laboratories, The Pfaudler Company, Elyria Division.

[3] Ashley, "The Colloidal Matter of Clay and Its Measurement," U. S. Geol. Surv., *Bull.* **388,** p. 17; Ashley, "Technical Control of the Colloidal Matter of Clays," Bur. Stand., *Tech. Paper* **23,** p. 33.

something of a continuous structure, the non-colloidal particles are held up by it. If the water is excessive, the structure is not continuous and cannot hold up the larger particles, and settling results.

Proper working qualities under a given set of conditions of application probably depend on a correct adjustment of the elements which enter into the above general mode of action.[1]

Suspending Power of Clay

"The ability of a clay to take up and to hold in suspension relatively large amounts of foreign material (such as sand, powdered minerals, etc.) without destroying its other properties is to be attributed to the presence of colloidal material which surrounds the foreign particles and thus binds them together."[2] There is probably a material difference in clays as to the amount of colloidal matter involved. "Almost any mineral, as well as various soluble salts, may be present in clays and modify the properties somewhat."[3]

Action of Electrolytes on Clay Suspensions

It is generally thought that the dispersed particles of clay are negatively charged.[4] When, through the addition of an electrolyte, charges of opposite sign are available, the negative charges are no longer effective and flocculation results. "The positive ion of the electrolyte is of most influence in effecting the precipitation, the acid ion taking little part."[5] Some hold that precipitation by an electrolyte is a definite chemical reaction, a double decomposition in fact.[6] Electrolytes are classified as "flocculators" and "deflocculators." The former class includes acids and neutral salts and the latter the stronger alkalis and the organic colloids. As to the quantitative phase of the problem, it is generally held that the valency rule applies.

To produce complete precipitation a certain concentration of ion is necessary.[7] This is termed by some the "threshold concentration," by others the "iso-electric" point.[8] Further additions have no increasing effect. If an excess of electrolyte is added all at once, the iso-electric point may be passed before coagulation occurs and the particles acquire a charge

[1] Ashley, Bur. Stand., *Tech. Paper* **23**, p. 16.
[2] *Ibid.*, p. 38.
[3] *Ibid.*, p. 33.
[4] Ashley, U. S. Geol. Surv., *Bull.* **388**, p. 17, 22.
[5] *Ibid.* p. 18, 22; Ashley, Bur. Stand., *Tech. Paper* **23**, p. 16; Alexander, "Colloid Chemistry," p. 33.
[6] Taylor, "Chemistry of Colloids," p. 109.
[7] *Ibid.*, p. 95.
[8] Ashley, Bur. Stand., *Tech. Paper* **23**, p. 16.

opposite to the one they had originally.[1] One investigator of colloid suspension says, "The velocity of coagulation is influenced by the manner of adding the electrolytes. The velocity is less the more dilute the solution by means of which the electrolyte is introduced. If a part of the electrolyte is introduced insufficient to cause coagulation and time allowed to elapse before addition of the remainder, the rate of coagulation is less than when the electrolyte is added all at once. The retardation is greater the greater the amount of the first addition and the longer the time elapsed between additions. By this method it seems to be possible to obtain a sol that will be permanently stable in the presence of a concentration of electrolyte that would coagulate if added all at once."[2] Another writer states that "the manner of adding the reagent has a marked effect on precipitation.....When added very slowly or a little at a time, a much larger amount is necessary for complete precipitation.....The slower the reagent is added the greater is the excess."[3]

The coagulating effect of salts varies with the valence. With certain sols it has a value of 1–60–600 for mono-, di- and trivalent ions.[4] With clays the effects are not so great. As to the relation between the concentration of colloid and electrolyte, it has been found in some cases that the concentration of anion necessary to produce flocculation increases with decreasing concentration of colloid for univalent, is practically constant for divalent, and varies almost directly with the concentration of the colloid for trivalent anions.[5] Certain studies in connection with the use of magnesium sulphate have led the present writer to the conclusion that the above statement as to bivalent anions applies to clay suspensions of enamel. Ashley states, however, that "the concentration of reagent in the solution may be of less importance in determining the final state of the system than the ratio of reagent to clay."[6]

A somewhat different point of view is suggested by one writer who says that "the plasticity of clays depends on the amount of hydroxyl ions present in the water. When this is large, the negatively charged clay particles will go into colloidal suspension. When the hydroxyl concentration is depressed, as by the addition of acid or depression of temperature, the clay will assume the gel condition and become plastic. For decreasing plasticity may be used all bases, organic and inorganic, all salts of strong

[1] Alexander, *op. cit.*, p. 32.

[2] "A Protection Effect in Suspensions Obtained by the Addition of Electrolytes in Amounts Too Slight to Involve Coagulation," *Chem. Abs.*, **18,** 3511(1924).

[3] Taylor, *op. cit.*, p. 98.

[4] Ashley, U. S. Geol. Surv., *Bull.* **388,** p. 22; Alexander, *op. cit.*, p. 33; Taylor, *op. cit.*, pp. 106, 109; Ashley, U. S. Bur. Stand., *Tech. Paper* **23,** p. 16.

[5] Barton and Bishop, "Coagulation of Colloidal Solution by Electrolytes—Influence of Concentration of Sol," *Jour. Phys. Chemistry,* **24,** 712 (1920).

[6] Ashley, Bur. Stand., *Tech Paper* **23,** p. 45.

base with weak acids, which hydrolytically split off OH ions in large amounts. To this classification belong potash, soda, salts of phosphoric acid, salts of silicic acid. Neutral salts with very few exceptions appear to behave indifferently. As indifferent salts are sodium chloride, sodium sulphate, potassium nitrate, magnesium chloride, and others. The causes of the abnormal behavior of some are not yet exactly known."[1] This general view is refuted by Ashley who says, "It seems more logical, though perhaps more difficult in details, to refer plasticity to the gel structure of the clays themselves, than to the vehicle. It must be allowed that the condition of the water will have effects of the nature assigned above. But as clay is plastic when wetted with materials not containing hydroxyl ions, hydroxyl can by no means play the principal part."[1]

The recent application of the conception of hydrogen ion concentration has been a most fruitful effort in a great variety of industries. The work of F. P. Hall[2] suggests a possible relation between hydrogen ion concentration and the flocculation of clays. It is not too much to hope that work along this line would bring results in connection with the present problem.

Effect of Organic Matter in Clay

The relation of the organic matter in clay to its colloidal properties is considered an important point by many. Recent discussions on the floor of this SOCIETY have dealt with this subject. Possibly some organic materials act as protective colloids.

"When a very stable sol in the presence of a less stable sol of the same sign is acted upon by an electrolyte that will not precipitate the former, but would precipitate the latter if alone, the influence of the more stable sol is often sufficient to 'protect' the less stable sol from coagulation. Non-colloidal substances can exercise protection. Gelatine is a common 'protection colloid' for many substances of small-sized ions. The colloids of clay may carry into suspension solid particles that are wholly non-colloidal by ordinary ideas."[3]

"Mixtures of two colloids of opposite signs cause a precipitation which is complete at a definite proportion; but addition of an electrolyte capable of precipitating one of the two colloids prevents their mutual precipitation. If, to mixtures containing a constant quantity of negative colloid A and increasing proportions of an electrolyte which does not precipitate this colloid, one adds a constant quantity of colloid B, it is noticed that for weak quantities of electrolyte the precipitate is a mixture of A and B, for increasing amounts of electrolyte the precipitate consists of B alone,

[1] Ashley, U. S. Geol. Surv., *Bull.* **388,** p. 21.

[2] F. P. Hall, "The Effect of Hydrogen Ion Concentration on Clay Suspensions," *Jour. Amer. Ceram. Soc.*, **7** [9], 989 (1923).

[3] Ashley, U. S. Geol. Surv., *Bull.* **388,** p. 20.

while for the strongest amounts of electrolyte the precipitate contains a mixture of *A* and *B*. The precipitate resulting from the mixture of two colloids of opposed signs can generally be dissociated by the addition of an electrolyte capable of precipitating one of the couples."[1]

Taylor says, with reference to colloids in soils, "Humus...is emulsoid in character...and acts as a protective colloid for suspensoid colloids in the soil." "As a negative colloid, humus is precipitated by kations... It alters the way the soil works."[2] With general reference to protective action Taylor says"...a suspensoid sol when mixed in suitable proportions with an emulsoid sol, loses most of its characteristic properties, and gains those of the protecting emulsoid."[3]

Alexander states that "the effects of vegetable extractive matters on the working properties of clay have been known from ancient times—in the Bible (Exodus V) it is mentioned that brick cannot be made without straw. Recently patents have been taken out for 'Egyptianizing' clay by adding to it tannin, extract of straw, humus and the like. Glue and similar protectives deflocculate or 'free out' clay and make it 'cover' in paper-coating and kalsomining."[4] And further "there are numerous organic substances...which act as protective colloids and tend to produce and maintain the...deflocculated conditions."[5]

The fact that more alkali is required to flocculate natural clay soils than kaolin suspensions has been attributed to the protective action of the humus present.[6]

Acheson improved the properties of certain clays by adding "humus."[7]

Action of Mill Liquor

If the action of electrolytes on the colloidal matter is the basis of the problem, the materials dissolved in the mill liquor cannot be overlooked as to their relation to the colloidal matter in the ground batch or to the electrolyte to be added in setting up.

Suggestive of the nature of mill liquor it may be well to record the results of a test made on the liquid which separated on top of a grind of a relatively insoluble enamel without mill addition. The colloidal matter in suspension in a 100 cc. sample was coagulated by ammonium chloride and filtered off. The filtrate was evaporated to dryness. Determinations on the coagulum and filtrate residue were made.

[1] Ashley, U. S. Geol. Surv., *Bull.* **388,** p. 31.
[2] Taylor, *op. cit.*, p. 290–91.
[3] *Ibid.*, p. 131.
[4] Alexander, *op. cit.*, p. 42.
[5] *Ibid.*, p. 44.
[6] *Ibid.*, p. 46.
[7] Ashley, U. S. Geol. Surv., *Bull.* **388,** p. 12.

COAGULUM

	Grain
Dried weight	.2624
Ignited weight	.2418
Loss in ignition	.0206
Silica	.1592

= 66.0% of ignited coagulum.

FILTRATE RESIDUE

	Grain
After gentle heating	.4149
Ignited	.3427
Loss on ignition (contained some NH_4Cl)	.0722
Silica	.0251

= 7.3% of ignited filtrate residue.

The high percentage of silica in the coagulum and the low amount in the filtrate residue are worthy of note. There must have been a considerable amount of alkalis and probably B_2O_3 in solution in the mill liquor.

Differences in Enamel

There is no doubt a difference in enamels as related to the action of clay. They may vary in solubility in the mill liquor. Depending on the fineness of grinding, more or less of the enamel substance proper may enter the colloidal state and call for flocculation later.

Applications

With the above or any other theory as the working basis, it becomes necessary to have a correct conception of the physical properties of the enamel slip as a means of making observations experimentally and correlating them with the practical phases of the problem.

E. C. Bingham has suggested[1] that our old habit of working in terms of a viscous liquid is wrong and that we should think of our enamel slip as a plastic solid whose behavior is to be judged in terms of "mobility" and "yield point." This line of reasoning as applied in certain industries has brought most encouraging results. R. D. Cooke has made a preliminary application to our problem and more work along this line may be expected to throw much light.[2]

The purpose of this presentation has not been to proclaim any new ideas or to herald the results of new accomplishments, but to stimulate thought

[1] E. C. Bingham, "Discussion on Plasticity," *Bull. Amer. Ceram. Soc.*, 3 [10], 375–79 (1924).

[2] R. D. Cooke, "Plastic Properties of Enamel Slip," *Jour. Amer. Ceram. Soc.*, 7 [9], 651–55(1924).

and research of a fundamental nature. It is hoped that a discussion of the ideas presented may be had that will promote the end in view.

Among books, in addition to the references given, well worth study are the following:

"Handbook of Colloid Chemistry," Oswald.
"Applied Colloid Chemistry," Bancroft.
"Fluidity and Plasticity," Bingham.
"Laboratory Manual of Colloid Chemistry," Holmes.
"The Chemistry and Physics of Clays and Other Ceramic Materials," Searle.
Transactions, *Journal* and *Bulletin*, AMERICAN CERAMIC SOCIETY.

THE PFAUDLER CO.
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LABORATORY EXPERIMENTS IN THE DEVELOPMENT OF A PLANT DRIER[1]

By Wayne E. Barrett

ABSTRACT

Experiments show that the direction of flow of air or other drying media should be parallel to the hollow spaces of hollow tile and drain tile. Its velocity should be approximately 60 feet per minute for maximum safe drying and its humidity may be reasonably low providing the temperature of the clay in the block or tile is high.

Introduction

In firing hollow tile and drain tile, it has been noticed that invariably when they are set wet in the kilns, they will finish drying and firing without cracking. At the same time, excessive cracking will take place in the waste heat drier when the same pieces are completely dried before going into the kilns. Analyzing the results for reasons why this should be, it was found that in the case of drying the tile, in the kilns, which are down-draft, the direction of the drying media was parallel to and through the cells of the block. While on the other hand, in the drier the direction of the drying media was perpendicular to the cells of the tile. Only eddy currents were responsible for the drying within the cells. Furthermore, since the warmest gases are lightest, they will be found at the top and the coldest at the bottom. Since drying will take place most rapidly in the presence of warm air, other things being equal, the tops of the tile dry first causing more or less strain and often cracking.

Procedure

Following the idea gained from the kiln, an experimental section of a drier was constructed as shown in Fig. 1. The idea in mind, was to build a drier that would periodically and automatically deflect the air through

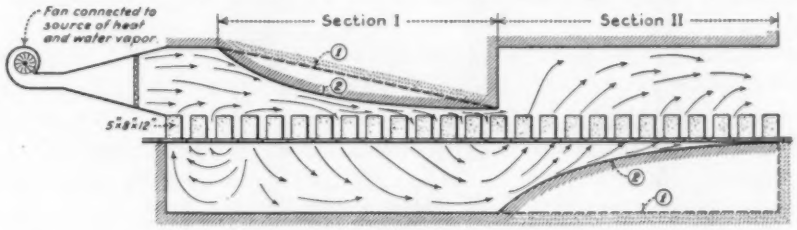

Fig. 1.

the tile as they passed through the drier. The roof and floor for deflecting the air were first built as shown by 1 (Fig. 1).

Actually drying green tile, it was found that the drying took place at the two ends of each section, the middle of each remaining relatively wet.

[1] Recd. Feb. 3, 1925. Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (Heavy Clay Products Division.)

A natural conclusion was that through induction, the air was being pulled through the tile in a reverse direction at the left hand end of each section. At the right hand end the air progressed as planned, while in the middle there was no vertical circulation up or down.

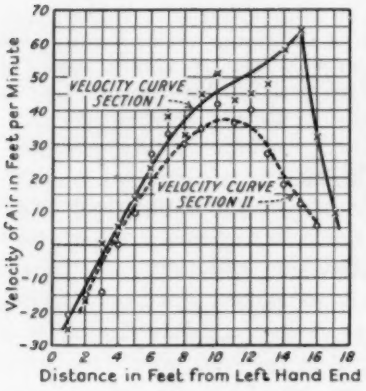

FIG. 2.

Using an anemometer to determine the velocity of the air through the block, the roof and floor were rechanged until they assumed some such position as 2 (Fig. 1). The velocity of the air downward in section I still remained unbalanced (probably due to the closeness of the fan), while the velocity upward in section II was in a relatively balanced condition.

Refilling the drier, the drying was repeated with results somewhat different, particularly in section II. Drying was more uniform from end to end of each section and without cracking. Ninety per cent of the total loss in weight (approximately factory results), occurred in 15 hours. The minimum safe drying time in the plant drier is 48 hours.

However it was noticed in section I that the tops of the tile still dried first. This was probably due to the fact that the air in reaching the right

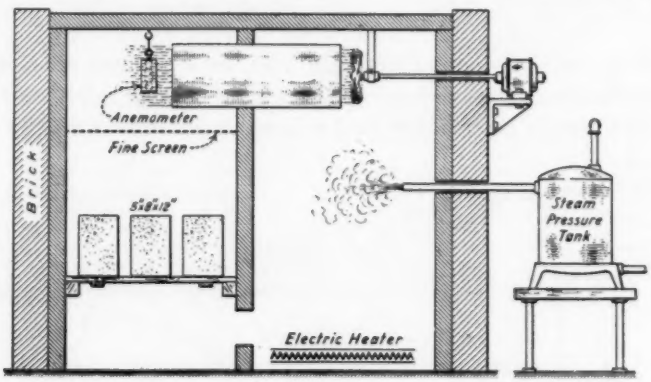

FIG. 3.

hand end had to pass over the tile in the left hand end. Since the pallets protected the bottom ends of the tile, this did not occur in section II. The air velocities through the tile are shown in Fig. 2.

Further experimentation to secure an absolute vertical movement of the air and more definite control was then started using the drier and equipment shown in Fig. 3, which is patterned somewhat after the Proctor drier.

In this drier 90% of the total water content was removed in nine hours without cracking the tile.

Results

By noting the curves of Fig. 4, it may be seen that as the humidity starts to drop, the rate of drying naturally begins to increase, and the rate of temperature rise of the tile begins to fall. What is taking place, is that the heat which had been going into the tile to raise its temperature, is now going into the evaporation of the water. A series of attempts to heat the block to a high temperature before starting the drying failed for the reason that the humidity of the surrounding air was too low. (Leakage of the drier prevented raising the humidity.) However, it is believed from these experiments, that had it been possible to raise the temperature of

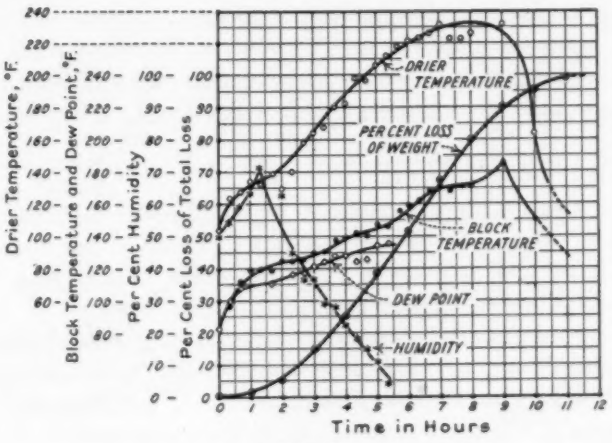

FIG. 4.

the tile to roughly 175°F that the drying would have taken place in half the time that they were actually dried in, and with disregard to all humidity conditions.

In plotting out the curve of the dew point, it was found to be below the temperature of the block, and oddly enough, it was found to be about the same number of degrees below for almost every different rate of raise of temperature in the drier. This would indicate that the drying might have taken place even faster than it did if the humidity had been lowered.

Conclusions

The conclusions to be drawn from these experiments are, that the drying media must travel in a direction that will strike all the surfaces equally and in a positive manner; that the drying may take place very rapidly

providing the shrinkage is uniform all over the tile; that the velocity, for maximum safe drying of the air, should not be over 60 feet per minute;[1] that if the tile are heated to a very high temperature, the drying may proceed much more rapidly than if the tile are at a low temperature; that a type of drier that would give a circulation of air through the tile instead of along its sides would speed up drying safely. These things are taken care of in the Proctor type of drier, but due to their great expense and the expense of operation, the type of drier as shown by Fig. 1 would almost as effectively do the work and at a much lower cost of construction and operation.

ADEL CLAY PRODUCTS CO.
ADEL, IOWA

[1] This is the velocity that H. D. Tiemann (in charge of the timber physics and kiln drying experiments of the U. S. Forest Service, Forestry Products Lab., Univ. of Wis.) has found to be the maximum safe velocity for drying lumber.

THE PARTICLE ANALYSIS OF CLAYS BY SEDIMENTATION[1]

By Edward Schramm and E. W. Scripture, Jr.

ABSTRACT

As a result of the analysis of Odén, it is possible to apply the sedimentation method quantitatively to the determination of particle distribution of clays in the dispersed state. An experimental procedure is described by which a number of points on the curve may be determined without the aid of any special apparatus. Sedimentation without the aid of a deflocculating agent gives valuable information as to the condition of the clay. Flocculated clays behave like jellies and the method of particle analysis cannot be applied in this case. Data concerning the usual physical properties are presented and these are found consistent with the results of the sedimentation tests as confirmed by microscope observations. The dispersed and fine grained clays are characterized by high dry strength, and the effect of deflocculating a clay is to increase its dry strength.

Introductory

During the past few years there have appeared a number of papers describing the application of sedimentation to the determination of distribution of particle sizes in fine grained materials.[2] These are all based on the work of Sven Odén[3] which was reviewed by Svedberg and Rinde.[2]

According to Stokes' law, $r^2 = \frac{9}{2}\frac{\eta h}{(\Delta - \delta)gt}$ in which r is the radius of a sphere of material of density Δ, which will fall through a height h in time t in a liquid of density δ and viscosity η. For water at 20° we may take $\delta = 1$, $\eta = .01$. With h in cm., t in seconds, $g = 980$, we calculate r in cm. If we have a clay suspension containing particles of all sizes falling through all heights from zero to some definite value, the rate of accumulation of sediment will evidently depend on the distribution of particle sizes. Odén analyzed this case, showing that if we express the amount of material settling as percentage of the total originally in suspension, the result for a given time and height of column is independent of the strength of the suspension; furthermore, if the results with different heights of column are corrected to a unit basis (a proportionate correction being made in the time) the results are independent of the actual height of the column. Odén weighed the amount of sediment accumulating on a plate suspended on a balance, adding small counterweights to maintain the balance equilibrium. He derived the relation

$$\frac{dS}{dr} = -\frac{2t^2}{r}\frac{d^2P}{dt^2}$$

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[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (White Ware Division.)

[2] Schurecht, *Jour. Amer. Ceramic Soc.*, **4**, 812 (1922); Svedberg and Rinde, *Jour. Amer. Chem. Soc.*, **45**, 943 (1923); W. J. Kelly, *Ind. Eng. Chem.*, **16**, 928 (1924); Kraemer and Stamm, *Jour. Amer. Chem. Soc.*, **46**, 2709 (1924).

[3] Odén, *Proc. Roy. Soc. Edinburgh*, **36**, 219 (1916).

where dS is the percentage mass of particles corresponding to the radius interval dr, t is the time of fall, and P the total percentage weight of sediment corresponding to the time t. r may be calculated from Stokes' law for the time t. Svedberg and Rinde[1] showed that the values $\frac{dS}{dr}$ can be obtained by a simple graphical method. The percentage weight of sediment, P, is plotted as ordinate against the time, t, as abscissa. If we draw tangents to the curve at points corresponding to the time t_1 and t_2, the difference between the intercepts on the weight axis gives directly the percentage of material of sizes between r_1 and r_2 as calculated from Stokes' law for the times t_1 and t_2 (see Fig. 1).

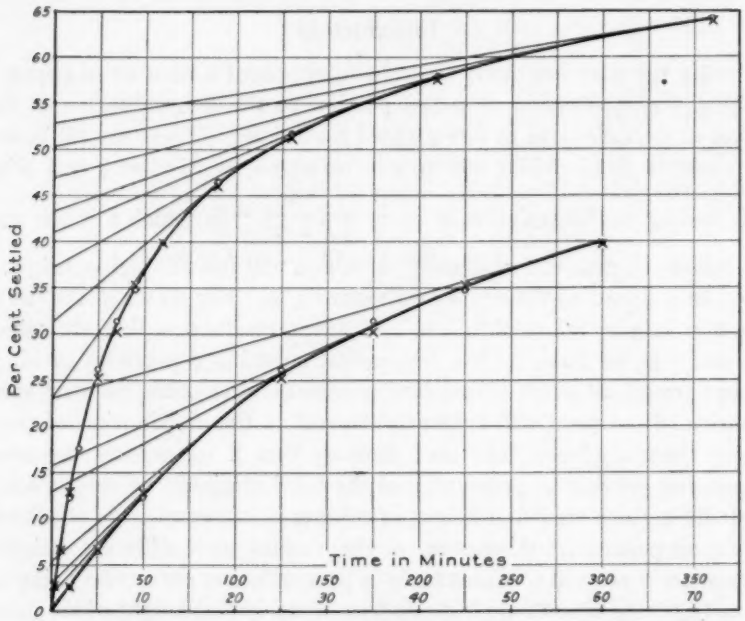

FIG. 1.—Clay No. 2.

The correctness of this method of analysis depends on the validity of Stokes' law which is strictly true only for spherical particles. In considering particles of various shapes, Odén found it convenient to define r as the mean effective radius, *i. e.*, the radius of a sphere which will have the same time of fall as the particle in question. The greater the proportion of flat or flaky particles, the more uncertain will be the results, but the method will nevertheless give a valuable approximation which is all that can be achieved by any known procedure, and as will be shown below, can

[1] *Loc. cit.*

be carried out experimentally with no special apparatus of any kind. To give some idea of the degree of accuracy Odén gives the following comparison for a sample of Swedish soil:

r (μ)	r' (μ)
78	100
24.8	30
8.3	10
2.9	3
1.03	1

In the above r is the mean effective radius calculated according to Stokes' law and r' the mean radius according to microscope measurements by Atterberg.

Svedberg and Rinde refined Odén's method by substituting for the addition of counterweights an electrical method of maintaining the balance which enabled them to work with smaller quantities of material and investigate colloidal metals. Kelly made use of the change in density as settling proceeded, measuring this by the recession of liquid in a capillary side tube. All of these methods are continuous, giving a great number of points on the accumulation curve. It appeared to us that the general procedure offered promise as a means of studying the structure of clays, more especially of the ball clays and refined kaolins. By contenting ourselves with the determination of a dozen points which are ample to define the curve accurately within the practicable working range, we were able to secure the data with a set of test-tubes and a wooden rack.

Experimental

The procedure adopted was as follows: We selected one dozen test-tubes of Pyrex glass 300 mm. long, 32 mm. outside diameter and of as uniform bore as possible. Exactly 20 cc. of water was introduced into each tube and the position of the meniscus marked with a label. A second mark was made on the tubes at a definite height (221 mm.) above the first. The volume between the marks was then determined by running in water. We now had a fixed height between the marks, a fixed volume below the lower mark, and a known total volume for each tube. To determine the accumulation curve the tubes were placed in two rows in a wooden rack designed to hold them vertical, filled with clay slip and shaken together. At stated intervals, the suspension was siphoned off down to the lower mark, the residue transferred to a weighed dish, evaporated to dryness and weighed. While the tubes are being filled the slip is kept in agitation by a motor driven stirrer. A portion of slip is also siphoned into a graduated flask and this is evaporated down for the determination of the strength of suspension in each experiment. Knowing the concentration we can

calculate the weight of clay between the marks in each tube and the weight below the lower label in all the tubes; the latter is subtracted from the weight of residue to give the weight of clay which has settled from the column between the marks. It is sometimes difficult to fill and draw the tubes accurately to the mark with a siphon and the final adjustment may be made with a pipette. Since the viscosity of water varies with temperature it is important to keep the latter as nearly constant as possible.

Needless to say, if we are to get a true picture of the distribution of particles the sample of clay must be completely deflocculated. The behavior of flocculated and deflocculated clays on sedimentation differs not only in degree but also in kind. The flocculated clays are gelatinous and settle like a mass of jelly; the particles or groups of particles do not fall freely in a viscous medium and Stokes' law is inapplicable. The volume of jelly-like sediment after settling is proportional to the degree of flocculation. With deflocculated clays the particles fall freely and the sediment is dense in character. The direct sedimentation of clays with distilled water is therefore valuable chiefly as a qualitative test for dispersion and can tell us nothing about the size of the ultimate particles. Some experimental observations bearing on this point will be presented later.

Water glass (of the composition $Na_2O.2.8SiO_2$) was used as a deflocculating agent because of the wide range of concentrations in which maximum effect may be obtained with different clays. As a result of preliminary experiments it was found that a proportion of 0.75% $Na_2O.2.8SiO_2$ of the weight of clay gave best results with a number of clays and this ratio was adopted as standard.

Specific gravity determinations on nine clays gave an average figure of 2.632 which was used in calculations from Stokes' law.

The usual procedure was to crush the clay in a mortar, make up a 5%

TABLE I

China Clay No. 1				China Clay No. 2			
Time, min.	Per cent settled	Time, min.	Per cent settled	Time, min.	Per cent settled	Time, min.	Per cent settled
2	4.3	2	4.1	2	2.68	2	2.74
5	7.8	5	7.1	5	6.43	5	6.66
10	12.4	10	12.4	10	12.3	10	12.9
15	17.0	20	21.0	15	17.6	15	...
25	22.8	30	26.6	25	26.2	25	25.2
35	28.9	..	..	35	31.4	35	30.2
45	34.0	45	32.5	45	34.8	45	35.3
60	36.4	60	36.6	60	39.9	60	39.8
90	43.3	90	43.0	90	46.5	90	46.0
130	49.3	130	48.7	130	51.7	130	51.2
210	56.4	210	55.6	210	58.0	210	57.7
..	..	360	61.8	360	64.3	360	64.1

suspension with the proper addition of water glass, blunge one hour, let stand over night and reblunge in the morning before filling the tubes. In the case of ball clays the slip was passed through a fine screen to remove coarse organic matter before sampling. The clays investigated comprised 7 English china clays, 1 English ball clay, 1 Tennessee ball clay, 1 Florida secondary kaolin, 1 North Carolina specially refined primary kaolin.

To show the reproducibility of results we give in Table I and in the curve data from separate runs on two English china clays.

To show the validity of using a 5% suspension, we give in Table II a comparison of results obtained with 1% and 5% suspensions. Working with 1% suspensions, weighings are made to 1 mg., with 5% to 10 mg.

TABLE II

China Clay No. 3

Time, min.	Per cent settled: 1% susp.	5% susp.
2	4.15	3.72
5	10.6	8.5
10	18.1	16.0
15	24.7	23.0
25	33.4	31.3
35	38.9	37.0
45	45.0	42.5
60	48.6	47.5
90	55.2	54.2
130	60.9	60.2
210	67.8	67.1
360	72.2	73.3

The data for the remainder of the clays are given in Table III.

TABLE III

Per Cent Settled

Time, min.	English China Clays: No. 4	No. 5	No. 6	No. 7	Eng. ball	Tenn. ball	Fla.	N. Car.
2	2.9	1.47	2.15	2.54	2.56	0.55	6.14	0.4
5	6.7	4.0	4.85	5.75	5.66	0.83	11.3	1.34
10	12.1	7.9	9.8	11.0	9.32	2.05	17.5	3.3
15	16.4	11.4	13.0	15.0	11.3	3.28	22.1	4.9
25	22.4	16.7	18.8	20.9	14.4	5.00	28.1	8.6
35	27.5	21.6	22.7	25.1	15.9	7.44	31.2	11.6
45	30.5	25.0	26.3	27.8	18.6	8.88	35.6	14.3
60	33.6	28.2	29.4	31.5	20.0	11.2	38.8	17.1
90	39.9	33.9	34.5	36.1	23.3	15.1	44.0	22.6
130	45.4	38.2	38.8	40.5	26.1	20.1	48.0	27.2
210	53.2	46.0	44.8	46.4	30.9	26.6	53.3	33.4
360	57.6	52.5	51.4	53.2	35.4	33.5	59.1	39.6

TABLE IV

DISTRIBUTION OF PARTICLE SIZES

Time, min.	Range of sizes radius μ			English China Clays Per cent							Per cent			
				No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	Eng. ball	Tenn. ball	Fla.	N. Car.
5	>	14.3		2.1	0.3	0.4	0.5	0.1	0.3	0.5	1.2	0.0	4.4	0.0
10	14.3	to	10.3	0.7	1.5	1.6	2.1	0.5	0.9	1.2	2.8	0.0	2.2	0.0
15	10.3	to	8.3	1.8	1.2	6.0	2.4	1.1	1.3	2.1	2.3	0.0	3.4	0.0
20	8.3	to	7.2	2.2	2.3	2.8	1.7	1.9	2.5	2.5	1.1	0.0	3.3	0.0
30	7.2	to	5.9	3.6	7.7	4.1	4.1	1.6	3.6	4.9	1.2	0.0	4.4	0.9
40	5.9	to	5.1	5.4	2.7	4.2	6.4	3.8	2.2	2.2	0.6	1.3	2.7	1.7
60	5.1	to	4.1	7.2	7.3	12.5	3.2	7.2	6.6	6.2	3.5	1.1	4.6	2.4
90	4.1	to	3.2	3.5	8.2	5.0	2.1	3.5	3.8	4.8	2.6	1.0	7.5	4.6
130	3.2	to	2.8	6.7	6.0	7.9	4.4	4.3	5.3	3.8	1.7	2.6	4.6	5.3
160	2.8	to	2.5	4.3	3.8	4.7	3.5	2.0	2.2	2.8	1.2	3.6	2.2	1.7
200	2.5	to	2.3	3.5	2.2	2.9	6.6	3.6	2.9	1.8	2.1	3.7	1.9	2.2
250	2.3	to	2.0	4.8	3.6	4.2	7.0	5.6	2.1	2.5	3.7	1.9	3.4	4.5
300	2.0	to	1.85	4.0	3.6	4.0	3.2	5.0	3.8	3.6	2.4	2.8	2.9	3.5
350	1.85	to	1.7	2.0	2.4	3.1	3.3	2.3	3.4	3.1	1.6	2.8	2.7	4.0
	<	1.7		48.2	47.2	36.6	48.5	57.5	59.1	58.0	72.0	79.2	49.8	69.2

These percentages were plotted against time and tangents drawn to obtain the distribution of particles as previously described. A typical curve is given. The first part of the curve was plotted on a more open time scale to enable the tangents to be drawn more accurately. The distribution figures are given in Table IV.

It will be obvious that of the particles remaining in suspension at any time none should exceed the radius calculated from Stokes' law for that time. This affords a rough method of checking with the microscope the correctness of the results. Slides were prepared from the siphoned-off suspensions by the method described by Weigel.[1]

About a dozen of the largest grains in each slide were measured with the aid of an eye-piece grating. The result for Clay No. 1 expressed in μ was as follows:

r (observed)	18.2	15.6	12.0	9.7	7.8	7.0	6.0	3.9	3.6	2.6
r (calcd.)	22.8	14.3	10.3	7.2	5.9	5.1	4.1	2.8	2.3	1.7

The observed diameters are generally greater than the calculated. This is to be expected since with the microscope we are measuring the maximum rather than the mean radius of the particles.

It was early observed that if the deflocculating agent were omitted and if the clay was naturally flocculated, the suspension settled as a jelly leaving clear liquid above. If we attempt to apply the method of analysis herein described to such a system, we get an anomalous result; the rate of settling at the start is *slower* than with a dispersed system although in the latter case we do not get a clear liquid for long periods of time. If the floccules were falling freely as individuals, we should, of course, have a very much faster rate of settling. However, the sedimentation of the clay in its natural state in distilled water gives valuable information to supplement the particle analysis. A series of observations on the clays here investigated is given in Table V.

TABLE V

UNTREATED CLAY SUSPENSIONS

Clay No.	Division between liquid and suspension	State of liquid	State of sediment	General
1	Sharp	Very clear	Loose and bulky	Flocculent
2	Sharp	Fairly clear	Loose and bulky	Flocculent like No. 1 but liquid slightly turbid
3	Sharp	Perfectly clear	Loose and bulky	Flocculent
4	Indistinct	Very turbid	Very compact	Dispersed

[1] W. M. Weigel, "Size and Character of Grains of Nonmetallic Mineral Fillers," Bur. of Mines, *Tech. Paper* 296.

TABLE V (*Continued*)

Clay No.	Division between liquid and suspension	State of liquid	State of sediment	General
5	Sharp	Fairly clear	Loose and bulky	Flocculent
6	Indistinct	Very turbid	Compact	Dispersed
7	Sharp	Very clear	Loose and bulky	Flocculent
Eng. ball	Indistinct	Very turbid	Very compact	Completely dispersed
Florida	Sharp	Fairly turbid	Somewhat compact	Characteristics of both flocculent and dispersed clays; former predominating
N. Car.	Indistinct	Very turbid	Somewhat compact	Partially dispersed; loose sediment, turbid liquid
Tenn. ball	Indistinct	Very turbid	Very compact	Completely dispersed

The above observations as to the nature of the clays were confirmed by the microscope. The flocculent and dispersed clays appeared in marked contrast, and clays like the Florida and North Carolina showed flocculated masses and dispersed fine particles.

We shall now present in tabular form a summary of the properties of the different clays:

TABLE VI

Clay No.	State of aggregation	% below 1.7 μ
1	Flocculent	48.2
2	Flocculent	47.2
3	Flocculent	36.6
4	Dispersed	48.5
5	Flocculent	57.5
6	Dispersed	59.1
7	Flocculent	58.0
Eng. ball.	Dispersed	72.0
Florida	Partly dispersed	49.8
N. Car.	Partly dispersed	69.2
Tenn. ball	Dispersed	79.2

It will be noted that the china clays may be of coarser or finer grain and either variety may be flocculent or dispersed. The ball clays, both English and American, are of very fine grain and completely dispersed. The secondary and primary American kaolins may be of coarse or fine grain and have some of the properties of both flocculated and deflocculated clays.

It will now be of interest to present data on other properties of these clays which may be interpreted in the light of the foregoing.

TABLE VII

PROPERTIES OF CLAYS

Clay No.	Fired cone	Per cent linear shrink.		Per cent absorp.	Per cent water of plasticity	Mod. of rupture	
		Drying	Total			Dry	Fired
1	11 started	2.08	7.28	23.4	30.8	57	2450
2	11 started	2.18	6.82	24.3	29.0	59	....
3	11 started	1.54	6.25	25.1	29.1	39	1710
4	11 started	3.09	10.62	19.0	34.3	180	3960
5	11 started	1.31	6.25	23.8	29.1	62	3090
6	11 started	2.56	9.90	18.4	..	194	4005
7	11 started	1.67	7.93	21.4	..	104	3990
Eng. ball	10 half over	5.5	15.3	0.0	..	452	5845
Florida	11 half over	7.0	16.6	13.8	..	242	6420
N. Car.	10 3/4 over	3.8	11.0	17.0	32.1	311	5170
Tenn. ball	10 3/4 over	4.0	11.1	0.0	..	385	8130

Considering the English china clays, it will be noted that Clay No. 3, which is coarse and flocculated, possesses the lowest shrinkage, highest absorption, low water of plasticity, and the lowest dry and fired strength. Clay No. 6, possessing the lowest absorption and highest dry and fired strength, is fine grained and dispersed. It is followed closely by No. 4, which is also dispersed, but of somewhat coarser grain. Of the remaining china clays which are all flocculated, No. 7, having the finest grain, shows the lowest absorption and highest dry strength. Nos. 1, 2, and 5 are intermediate in characteristics. Similar relations hold for the other clays. The ball clays, of very fine grain and completely dispersed, exhibit the highest shrinkage and dry strength.

These relationships are in conformity with the known plastic or working qualities of the clays. Both the plastic and the dry strength are affected by the distribution of particle sizes and the state of aggregation of the clay. The fired strength is probably also influenced by the same factors, though the case here is not so simple since the question of flux content enters.

If the views presented herein are correct, the deflocculation of a clay should result in increased dry strength. This has been proven by Schurecht,[1] who says: "The increase in mechanical strength may be largely due to the fact that the finer grains would pack more closely and hence make a denser body." To verify Schurecht's observations, china clays Nos. 1 and 7 were treated with the usual amount of water glass, brought to a plastic condition and made into briquettes. The dry strength of No. 1 was increased by the treatment from 57 to 80, of No. 7 from 104 to 185. The greater increase with No. 7 is due to the greater fineness of

[1] H. G. Schurecht, "The Use of Electrolytes in the Purification and Preparation of Clays," Bur. of Mines, *Tech. Paper* **281** (1922).

the ultimate particles and the treatment has brought it in the class of Nos. 4 and 6 which are initially deflocculated.

Obviously the rate of drying will depend on the physical structure of the clay. We determined this rate for four china clays under arbitrary conditions; the clays were brought to a similar plastic condition and made into small briquettes which were placed in an oven and removed after one hour at 35°C, one hour at 50°, one hour at 60°, and heating to constant weight at 110°. The clays so studied were a relatively coarse grained flocculent clay (No. 2); a fine grained flocculent clay (No. 7); a relatively coarse grained dispersed clay (No. 4); a fine grained, dispersed clay (No. 6). The results are given in Table VIII.

TABLE VIII

DRYING BEHAVIOR

Per Cent Loss in Weight

Clay	1 hr. at 35°	1 hr. at 50°	1 hr. at 60°	Constant weight
2	4.8	12.3	23.6	25.7
7	4.2	10.8	22.0	26.5
4	4.3	11.7	22.5	30.6
6	4.0	10.6	23.0	29.7

The clays of finest grain (7 and 6) have the slowest initial drying rate, while the dispersed clays (4 and 6) have the highest water of plasticity.

Summary

As a result of the analysis of Odén, it is possible to apply the sedimentation method quantitatively to the determination of particle distribution of clays in the dispersed state. An experimental procedure is described by which a number of points on the curve may be determined without the aid of any special apparatus. Sedimentation without the aid of a deflocculating agent gives valuable information as to the condition of the clay. Flocculated clays behave like jellies and the method of particle analysis cannot be applied in this case. Data concerning the usual physical properties are presented and these are found consistent with the results of the sedimentation tests as confirmed by microscope observations. The dispersed and fine grained clays are characterized by high dry strength, and the effect of deflocculating a clay is to increase its dry strength.

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AMERICAN CLAYS AS COMPARED TO ENGLISH CLAYS IN WHITE WARE BODIES[1]

By E. H. Fritz

ABSTRACT

A summary of the discussion at Atlantic City on this subject is given, bringing out Dr. Langenbeck's charge that the failure to make wider use of American clays is due to the ceramic profession, which has not given American clay producers specific information as to requirements which must be met in order to compete with English clays.

This charge is refuted, because such information is available and various tests which are made are enumerated. The charge is made that many clay producers either do not know how, or, are not sufficiently interested to make use of such information when it is given them.

Comparative results with English and American clays are given in regard to general uniformity, plasticity, bonding strength and vitrification. Equal or better results were obtained with the American clays in every case except vitrification temperature of the ball clays which was somewhat higher.

A body was developed from the best American clays which equaled any of the English clay bodies, the difference in vitrification temperature of the ball clays apparently having no adverse effect at a firing temperature of cone 10. The results are based on commercial use.

It is concluded that English clays can be eliminated in most white ware bodies.

At the Atlantic City Meeting, a year ago, a very interesting discussion[2] was led by Dr. Langenbeck on "What has been the experience in substituting domestic secondary and primary kaolins for English china clays?" and ball clays were also included by his consent. The consensus of opinion of those taking part was:

1. While the uniformity of all clays cannot be guaranteed, English clays will average more uniform than the American.
2. English ball clays have a lower vitrification temperature than the American.
3. English clays have better plasticity and greater bonding strength.
4. Better color can be expected from the English material, especially china clays.

The discussion also brought out two cases of successful substitution of American clays for the English. No specific information was given as to the kind of tests which had been used upon which such substitution had been based, nor did any one else who was attempting to substitute American clays give any information as to the kind of tests employed. As a result, Dr. Langenbeck, charged the apparent failure to make wider use of American clays, to the ceramic profession, for, he claimed, that the American producers had been given no definite information as to what

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (White Ware Division.)

[2] *Bull. Amer. Ceram. Soc.*, **3** [11], 417–34 (1925).

requirements they had to meet in order to compete with the English clays.

We were one of the two cases of successful substitution, making use of American clays in our dry press electrical porcelain work, which we have been doing for some time. The failure of myself and the others to give information as to the tests employed, was, I am sure, not due to not having any, for I believe, all of us make use of the same simple tests which have been in use for some time. At our plant we determine the water of plasticity, rate of slaking, amount of residue on 150-mesh lawn, modulus of rupture in the unfired state, dry shrinkage, firing shrinkage and vitrification which is determined by the per cent of absorption at cone 10. This is our preliminary test, and, if the results are within the limits specified for each property, we substitute the clay for a similar clay in our regular body mix, making up about six hundred pounds of this body with laboratory equipment. This equipment duplicates as closely as possible the equipment used in the factory. From this body we make up standard insulators, having them made by men in the factory who are capable of giving an accurate opinion as to how this body compares with the regular body mix. We consider this a very important test, especially as to plasticity and workability. If the results of this trial are satisfactory, we purchase a carload of the clay and use it in the factory in the regular way, keeping accurate records of manufacturing losses and finally test the quality of the finished product. This constitutes the final test. This method of testing is not as accurate as I would like to see it, for it is quite possible that a clay will pass the preliminary tests and then fail on the final factory trial on account of higher losses. It is often impossible to find the reason for this and in such a case we cannot tell the producer why his clay is not satisfactory. It is, however, the best that is available for our purpose at the present time.

The test for plasticity, upon which we depend, is especially crude and has been condemned by some writers; but I find that although it is apt to be inaccurate at times, it is by far the most dependable test that we have ever used. We have been doing considerable work during the past year on the Bingham plastometer method of determining plasticity. This shows considerable promise and we hope to be able to apply this test in a routine way before long.

I am not in agreement with Dr. Langenbeck, therefore, in his deduction that lack of progress in testing clays has prevented free competition between English and American clays, for comparable data on many similar clays is available to the producers. Regardless of the nature of the tests employed, however, it is extremely doubtful to me, that such data would be of any assistance to most of the clay producers in meeting the requirements. I have often told producers what type of clay we wanted, in terms of test results, and instead of telling me that they did or did not

have such a clay, in most cases their answer is "Test ours and see if it will do." I am reminded of another case where a ball clay became variable in vitrification. Upon bringing this to the attention of the producer the reply was that they were selecting the clay according to a fixed standard which was based on appearance, and beyond this they could not guarantee it free of variation. In other words, they could not control vitrification and were not sufficiently interested to investigate this variation.

Since the time of the last Meeting we have done considerable work on the substitution of American for English clays in our plastic process body. Our results with the English clays showed:

1. Some ball clays are exceedingly variable especially in plasticity. This was indicated by the great variation in the amount of water necessary to blunge the body in which such clays were used. This variation was as high as 100%; that is, the maximum was twice the minimum amount of water used. There was naturally a difference in the workability of this material in the plastic form, which, of course, is disastrous for manufacturing operations.

2. The china clays as a class are weaker and less plastic than a good standard Georgia kaolin. They were more apt to tear under the trimming wire, causing higher drying and firing losses.

3. Some of the English clays, especially some ball clays, gave us more trouble on account of their individual variations, than we ever had with any American clay.

With American clays we found similar variations in the ball clays as were found with the English clays, but they were not as great. This leads me to believe that American miners who know their business and have an established reputation, are more selective with their clays than English miners. Successive carloads of some English clays were so different in appearance, that I am quite sure the American miner would never have thought of shipping it under the same name, at least, I have never seen American clay come in that way. My opinion, therefore, in regard to comparative uniformity has been changed and I believe now that the advantage in this respect lies with the American clays.

Regarding plasticity and bonding strength, as just mentioned we found English china clays inferior to the best Georgia clays. English ball clays average better than the American in these properties, but we did find a few Tennessee and Kentucky balls, which, when used in combinations, were equal to the best English balls.

We were still not able to find any American ball clay whose vitrification temperature was as low as that of most English balls. The nearest result obtained was cone 9, which is considerably higher than that of most any English. In color there was no apparent difference between the two classes when fired in body mixes. This is not a true comparison, however, for

we did not use the whitest burning English clays, because this property is not essential in our work. There is no doubt but that there are some English china clays which are superior to any others in color.

In only one respect then, vitrification, were we unable to equal the English clays. This difference, however, had no effect in the body in which the best American clays were substituted for English. This is probably due to the fact that at our firing temperature of cone 10, the ball clay would be vitrified anyway. However, if any difference would result in the firing behavior of the body, it should be possible to adjust it by means of a slight increase in the feldspar content.

A body was thus developed in which American clays only were used, and which gave equal results to the best of the English clay type, not only from the standpoint of manufacturing losses, but also, and what is more important, from the standpoint of quality as shown by tests of the finished product. My conclusion, therefore, is that English clays can be eliminated in most white ware bodies since ours is close to the general type of this class. This deduction is not as yet based on extensive use, but we have made a factory trial of the body which I spoke of which extended over a period of several weeks. As a result of this I am satisfied that the substitution can be successfully made. This means that we are placing some American clays on a competitive basis with English, and they have the added advantage in that a more intimate contact can be maintained with the producers on account of their proximity.

WESTINGHOUSE HIGH VOLTAGE INSULATOR CO.
DERRY, PA.

FINE STONEWARE FROM FLINT CLAY

By Paul E. Cox

ABSTRACT

Based on an observation by Karl Langenbeck[1] in his "Chemistry of Pottery" a fine and very dense stoneware fired at cone 9 has been developed with a Missouri flint clay as the principal raw material. The resulting product is non-absorbing, tough, and a very satisfactory body for ball mill jars, fine art stoneware, and any work where such a body is desired. Plasticity is equal to that of any standard that may be chosen and the body mixture can readily be thrown on the potter's wheel. Control of plasticity can readily be had so that such a body is available for use by any process. The color when fired is that of a poor grade of hard porcelain.

Introduction

Karl Langenbeck, in his "Chemistry of Pottery" says that yellow ware could be made from flint clays, provided wet grinding was done in the preparation of the clay. This idea has been put to a practical test with very satisfactory results, though a yellow body did not result.

The body composition is as follows:

The Flint Clay The flint clay is one from Mokane, Missouri. Its deformation point is cone 34. Its analysis is as follows:

SiO_2	43.71	MgO	0.56
Al_2O_3	39.63	Alkalis	.35
Fe_2O_3	1.27	Ignition loss	14.08
CaO	.40		
			100.00

This was prepared by reducing to dust in the laboratory wet pan, after which the body was prepared by wet grinding in ball mills, and by drying out to a workable condition on plaster.

The Body

The body composition is as follows:

Mokane flint clay	60
Kentucky ball clay	19
Feldspar	14
Bell Fourche, S. D. bentonite	7
	100

The first trials were made without the bentonite but proved impossible to form by the throwing process and the body cracked badly in plaster molds. After the bentonite was added, no trial was made in plaster molds,

[1] Karl Langenbeck, "Chemistry of Pottery," p. 68.

though there is no possibility that the body will not be possible to work in any desired manner. The thought was that the Kentucky ball clay would suffice for plasticity, following Langenbeck's suggestion to the effect that wet ground flint clays would become very plastic. In this case there was little plasticity in the flint clay. In fire brick practice, however, this flint clay will develop sufficient bonding power to bond itself in brick manufacture.

Properties of the Body

In the clay state this body works ideally. Vase forms are readily thrown from it, and can be drawn thin enough on the wheel so that finishing of the foot is all the additional work needed. Ball mill jars holding about a gallon were readily made by the stoneware potter's method on the wheel. The fired body is almost as white as many coarse porcelains, gray white in color, very dense, so dense that ink will not pentrate and the body matures at cone 9. The best biscuit temperature where a soft biscuit is desired is at cone 06. Used in ball mills, the body is entirely satisfactory in every way, and could readily be formed into large sized jars. The body was ground to pass a 100-mesh sieve.

Glazed Wares from the Body

A vase made from the body, was glazed in a mixture of the following composition:

$$\left.\begin{matrix} K_2O & .30 \\ CaO & .35 \\ ZnO & .35 \end{matrix}\right\} \; Al_2O_3 \quad .40 \left\{ \; SiO_2 \quad 4.50 \right.$$

This was stained with 10% of a blue stain such as is commonly sold for use as an underglaze color. This glaze proved a little too stiff and probably would be good if the silica content was reduced to 3.50. No crazing was manifest and the fitting of a glaze would not be at all difficult.

Conclusions

Flint clays will make first rate raw materials for use in fine art stonewares of the type produced by the European governmental porcelain factories, for ball mill jars and similar ball mill fittings, for floor tiles of the type used in mosaic floors, and for certain types of electrical insulators. Such bodies seem particularly fool proof in handling in the plant, because they form easily and are easily adjusted for several processes of manufacture and are easily fitted with glazes.

Acknowledgment

Credit is hereby accorded D. A. Moulton for the analysis, deformation point determination, and helpful suggestions about fire brick practice in the use of such clays.

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AMES, IOWA

CERAMIC ABSTRACTS

Compiled by the

AMERICAN CERAMIC SOCIETY

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[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from *Chemical Abstracts* by coöperative agreement.

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Abrasives

Corundum (South Africa). A. L. HALL. *S. A. Jour. of Ind.*, **7**, 801(1924).—Corundum occurrences in S. A., extent and situation of fields which are the most extensive on record; varieties of corundum; mode of occurrence, methods of mining and market preparation; quality of the corundum; and the manuf. of grain corundum are discussed. Statistical information, prospects of the corundum indus., a brief bibliography and a list of producers conclude this article. See also *Ceram. Abs.*, **3** [6], 188 (1924). O. P. R. O.

PATENT

Aluminous abrasive material and method of making the same. OTIS HUTCHINS. U. S. 1,524,134, Jan. 27, 1925. As a new article of manuf., fused aluminous mat. having more than 25% enclosed pores.

Art

PATENT

Fine ceramic products. WILHELM VERSHOFEN. Ger. Pat. 371,593. (*Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*, **48**, 130–2(1924).—To the clays employed before molding, water sol. fluoride compds. are added in order to start a chem. reaction in the mass. The molded article is easily hardened. W. S.

Cement, Lime and Plaster

Action of sugar on properties of Portland cement mortars. M. CONSTANTIN TSOUNTAS. *Rev. Mat. Constr. Trav. Pub.*, **182**, 281–3(1924).—The addn. of small

PORTLAND CEMENT. NO. 1

	Set in minutes	
	Initial	Final
Pure water	86	240
Water with 0.1% sugar	60	210
Water with 0.2% sugar	53	175
Water with 0.3% sugar	46	155
Water with 0.4% sugar	35	105

PORTLAND CEMENT. NO. 2

	Set in minutes		Tensile strength (Kgs. per sq. cm.)			
			Neat		1:3 Mortar	
	Initial	Final	7d.	28d.	7d.	28d.
Pure water	45	130	40.3	44.7	21.0	26.4
Water with 0.5% sugar	3	7	38.5	41.6	16.5	19.8
Water with 1.0% sugar	5	8	33.2	35.1	12.6	14.3
Water with 2.0% sugar	7	27	briquettes disintegrated			
Water with 3.0% sugar	7	36				
Water with 4.0% sugar	7	45				

quantities of sugar to Port. cement mortars has the effect of decreasing the time of initial and final set, lowering the strength of the resultant mortar, and causes a general weakening of the structure. It is assumed that the hydrated lime set free during the decompn. of the tricalcium silicate on the addn. of water, combines with the sugar to form saccharates of lime. The attack on the cement mortar and the resultant weakening is then proportional to the sugar content. See *Ceram. Abs.*, **3** [5], 119(1924).

L. N.

The behavior of the alkalis in cement during the water storage of cement and cement mortar bodies. V. RODT. *Cement*, **13**, 470–2(1924).—Of the total alky. dissolved during the storage of briquettes in distd. H_2O 30% was due to Na_2O and K_2O and 70% to CaO and MgO. The alkali:alk. earth ratio remained unchanged during storage in the absence of air. By using tap water and 0.0–0.9 g. sugar per 10 l., no CaO was found in soln. after 2 days while the amts. of NaOH and Na_2CO_3 increased with time of storage and concn. of the sugar soln. The effect of the sugar in delaying the set of the briquettes perhaps accounts for the increased alkali liberated.

H. F. K. (*C. A.*)

Mortar forming materials or mortar which is entirely impervious to humidity or passage of salts. J. H. DITTER. (Leipzig), *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*, **48** 130–2(1924).

W. S.

PATENTS

Hydraulic limes and cements from residues of furnaces. DORA ENGELMANN AND GEORG BLOESY. Ger. Pat. 368,082, *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*, **48**, 130–2 (1924).

W. S.

Enamel

Use sodium flux for iron. ANON. *Foundry*, **52**, 982–4(1924).—The addn. of 7 lbs. of soda ash to 1500 lbs. of molten iron in the ladle, reduced the sulphur .06%. M. E. M.

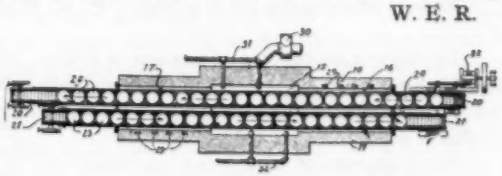
Vitreous enameling with the electric furnace. E. F. COLLINS. *Fuels and Fur.*, **2**, 1273–4(1924).—The use of the unmuffled radiant heat elec. fur. results in (1) freedom from contamination of product by combustion or other gases; (2) a negligible amt. of burned, blistered and improperly baked ware; (3) saving in floor space; (4) uniformity and a higher grade of ware; (5) good working conditions; (6) possibilities of using a conveyor type of baking fur.; (7) securing a vitreous coat that is adhesive and true to color; (8) a rapid heating of charge which can be controlled easily; (9) smooth, well covered edges free from defects. A table of cost data is given. W. E. R.

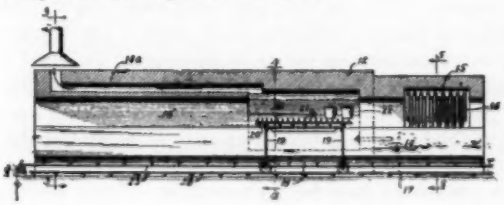
Waste heat recovered for use in drying vitreous enamel. ANON. *Fuels and Fur.*, **2**, 1283–4(1924).—A sheet metal recuperator in the fur. furnishes heat for the drying oven.

W. E. R.

PATENTS

Annealing furnace. HERBERT CHARLES BEASLEY. U. S. 1,526,583, Feb. 17, 1925. The method of annealing articles which comprises utilizing the heat stored





in annealed articles to heat articles to be annealed while said articles are in an oxidation-preventing atm.

Enameling furnace. HERBERT CHARLES BEASLEY. U. S. 1,526,582, Feb. 17, 1925. In an enameling fur., a firing or fusing chamber embodying means for

raising the temp. therein to an enamel fusing point, a preheating chamber situated at one end thereof, a cooling chamber situated at the other end of said firing chamber, means for passing articles successively through the preheating chamber, fusing chamber, and cooling chamber, and means for controlling, to a predetd. degree, the cooling effect of said cooling chamber, said last means comprising a conduit through which a heat-absorptive medium may be passed.

Glass

Applied "theory" in the glass factory. BJARNE SCHIELDROP. *Fuels and Fur.*, **2**, 1137–8(1924).—Some of the factors which influence the formation of defects in glass are: Change in temp. in the different parts of the fur.; change in the fuel supply; change in the air supply; variations in batch compn.; variation in the charging; variation in the flow of glass from the melting to the refining end; variation in stack draft. It is the duty of the practical man to run the tank and of the theoretical man to supply him applicable quant. information on points where eye-sight and quick diagnosis will necessarily be fallible. W. E. R.

Pyrometers for glass industry. C. B. THWING. *Fuels and Fur.*, **2**, 947–8(1924).—Certain difficulties in the application of pyrometers in the glass indus. have been overcome. W. E. R.

The principles and practice of annealing glassware. S. R. SCHOLES. *Glass Indus.*, **6**, 8–9(1924). D. E. S.

Design and operation of hot gas producer plants. W. S. MAYERS. *Glass Indus.*, **6**, 1–7(1924). D. E. S.

Colored glasses in hollow glass works. CARL DUVIVIER. *Glass Indus.*, **5**, 229–31(1924).—Trans. from *Le Verre*, **4**, 197–9(1924).—This article gives the proportions of various oxides used in making colored glasses and some of the precautions necessary to success. D. E. S.

Finishing sixty thousand lamp chimneys a day. E. W. KOERING. *Glass Indus.*, **5**, 203–6(1924). D. E. S.

Cost of the glass product. G. WESLEY EVANS. *Glass Indus.*, **5**, 223–6(1924). D. E. S.

Some glassmakers' problems and how they were solved. IRVING E. ADAMS. *Glass Indus.*, **5**, 162–4(1924).—This article describes the solution of a number of problems such as elimination of seeds from glass, prevention of devitrification and scum, improving color, etc., and tells in each case the alterations to batch, firing conditions, etc., which were necessary to obtain best results. D. E. S.

Factors affecting the life of a tank. F. C. FLINT. *Glass Indus.*, **5**, 183–4(1924). D. E. S.

Dr. Shively on the use of alumina in glass. ANON. *Glass Indus.*, **5**, 165(1924).—For best results Al_2O_3 should not exceed 1.5%. It increases durability and strength, lowers annealing point, lengthens working range and aids in preventing devitrification of glass. D. E. S.

Some aspects of tank block corrosion. S. R. SCHOLES. *Glass Indus.*, **5**, 161–2 (1924).—The theory is offered that grooves visible on tank side walls after long service are due to the sinking of heavy clay-bearing glass whereby fresh glass is continually presented to the clay surfaces which are attacked, and the cycle repeated. D. E. S.

Methods of analysis of the laboratory of the crystal glass works of Val-Saint-Lambert. AD. LECRENIER. *Glass Indus.*, **5**, 187–9(1924).—Translated from *Le Verre*, **4**, 125–8(1924).—This article gives methods and representative anal. of several of the mat. of glass manuf. D. E. S.

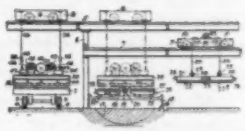
On devitrification phenomena in practice in glass factory operation. HUGO KNOB-

LAUCH. *Glass Indus.*, **5**, 206–10; 232–3(1924); **6**, 10–11(1925).—Trans. from *Sprechsaal*, **57**, May 23, 1924. D. E. S.

Quartz glass. ANON. *Chem. Eng. and Min. Rev.* (Melbourne), **17**, 114(1924).—Quartz glass for scien. purposes has been produced according to the Herberger method, by the German firm of Goertz for years. Finely divided quartz is melted in an elec. fur. in which a vacuum is maintained by continuous pumping until the whole is melted. The vacuum is then replaced by a gas such as carbon dioxide, under a press. of 8 to 12 atmospheres, and after considerable time the fused quartz is allowed to cool. The result is a block of quartz contg. only minute air bubbles in which the air press. is as nearly as possible that of the atmosphere, and therefore produces no elastic stress in the mat. It is considered that glass made in this way is as transparent in the ultraviolet as rock crys. O. P. R.O

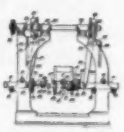
PATENTS

Turning plate glass. FRANK E. TROUTMAN and CHARLES H. CHRISTIE. U. S. 1,524,067, Jan. 27, 1925. The method of turning a plurality of pieces of flat glass without changing their relative arrangement, that comprises lifting the pieces of glass simultaneously by means of suction, placing the said pieces of glass simultaneously upon a support, placing another support upon said glass, inverting the said supports, removing the uppermost support, lifting said pieces of glass simultaneously from the lower support by means of suction, and depositing said glass upon a grinding or polishing table.

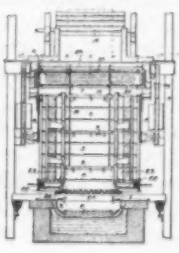


Method of obtaining varying charges of molten glass. WILLIAM A. LORENZ. U. S. 1,525,189, Feb. 3, 1925. The method of producing mold charges of different sizes for making glassware, which comprises severing a column of molten glass alternately at different locations in its path of discharge from a container.

Apparatus for obtaining charges of molten glass. WILLIAM A. LORENZ. U. S. 1,525,190, Feb. 3, 1925. App. for sepg. molten glass into mold charges of different sizes from glass discharged from the outlet of a container, comprising a plurality of severing means mounted to operate at different levels below the outlet, means for alternately actuating said severing means, and means for adjusting the levels to vary the propns. of the charges.



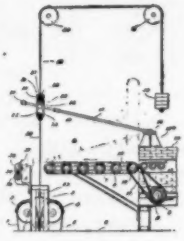
Apparatus for obtaining charges of molten glass. WILLIAM A. LORENZ. U. S. 1,525,191, Feb. 3, 1925. App. for sepg. mold charges of different sizes from a column of molten glass issuing from an outlet, comprising a plurality of coacting shearing devices mounted for movement below the outlet, independent means for supporting the respective severing devices, means for simultaneously reciprocating said severing devices on said supporting means, means for periodically changing the vertical positions of said supporting means in unison and at regular intervals prior to the time of severance to shift the paths of travel of said severing devices in a vertical direction, whereby said severing devices will sever the glass at different distances from said outlet.



Leer for annealing sheet glass. HALBERT K. HITCHCOCK. U. S. 1,525,132, Feb. 3, 1925. In a leer for annealing continuously formed sheet glass, a casing, means for advancing the glass sheet through the casing, heating units located on opposite sides

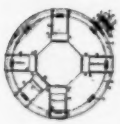
of the sheet, and other separate heating units located along the opposite edges of the sheet so that the cooling of the edges of the sheet can be controlled independently of the cooling of the faces of the sheet.

Sheet-glass clamp. GUSTAV EDWARD ERICSSON. U. S. 1,525,122, Feb. 3, 1925. In combination in a clamp for moving sheet material, a rigid inverted U-frame, block pivoted to the lower ends of the arms of the U-frame, opposing jaws mounted on the blocks for movement vertically and for a movement of approach when moved downwardly, positive operating means mounted above the jaws, and connections between said means and the jaws for moving the jaws upward relative to the frame.

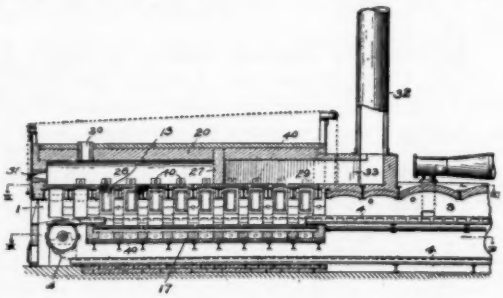


Apparatus for handling glass sheets. JOHN H. FOX. U. S. 1,525,124, Feb. 3, 1925. The combination with a vertical sheet glass drawing machine, of a counterbalanced clamping device above the machine adapted to engage the upper edge of the sheet and move upward therewith and give it support during and after the cutting-off operation, and a driven carrier extending laterally from a position adjacent the side of the sheet in position to receive the lower edge of the sheet when the clamp is in its upper position.

Method and apparatus for making plate glass. FLOYD V. KESSELMAN. U. S. 1,524,259, Jan. 27, 1925. The method of making flat glass that comprises delivering molten glass through a downwardly opening outlet in a succession of gobs or gathers, moving a series of casting tables in succession beneath said outlet through an annular path to receive said gobs thereon, and rolling said gobs into plates on said tables. App. for making flat glass comprising a rotatable support and a plurality of casting tables carried by said support and arranged to move continuously in succession beneath said feeder when said support is rotated, and a roll for each table arranged parallel and adjacent to the line of deposit of the glass on the table.

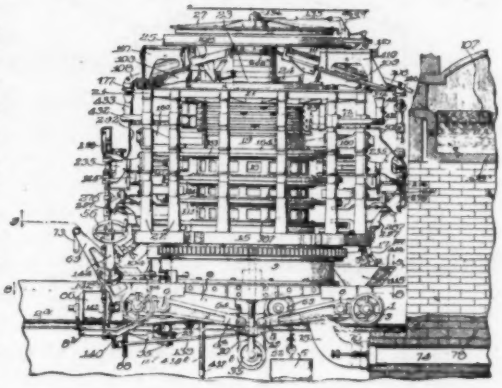


Annealing furnace. CHAUNCEY E. FRAZIER. U. S. 1,525,644, Feb. 10, 1925. In an annealing fur. the combination with a leer chamber of a fire-box overlying said leer chamber, a plurality of tunnel flues extending longitudinally beneath said leer chamber, a series of side-wall flues and transverse bottom flues connecting said fire-box with said tunnel flues, the side-wall flues toward the intake end of said leer connecting with one of said tunnel flues and the side-wall flues more remote from the intake end connecting with another of said tunnel flues, a chimney with which said tunnel flues communicate, and means for varying the draft conditions in the streams of flame and gas which flow from the fire-box to the chimney through the said severally connected sets of side-wall flues. In an annealing fur. the combination with a leer chamber, of an inlet chamber and a succeeding outlet chamber above the leer chamber, a plurality of longitudinal tunnel flues beneath the leer chamber, and a series of side-wall flues and transverse bottom flues connecting said inlet and outlet chambers with said tunnel flues, the side-wall flues near the opposite end of the furnace being

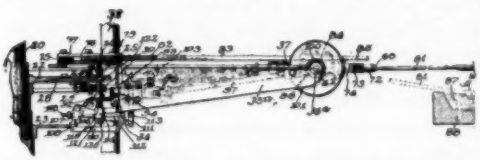


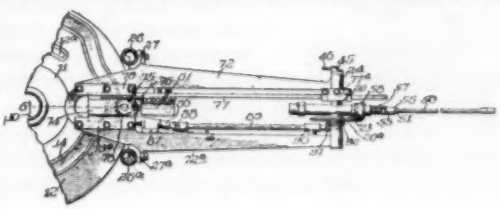
connected to one of said tunnel flues and the intermediate side-wall flues being connected to another of said tunnel flues.

Glass-working machines. AUGUST KADOW. U. S. 1,527,556, Feb. 24, 1925. The combination with a fur., of a continuously traveling support, gathering mechanism carried thereby, means for periodically actuating said gathering mechanism to gather metal from said furnace, said means comprising a traveling cam moving at a higher speed than said traveling support. The combination with blank forming means, of means for receiving the blank therefrom and for automatically swinging out the blank under air pressure. In a glass-working machine, the combination of a traveling support, a receptacle for receiving metal, carried thereby, means for arresting the travel of said receptacle without arresting the movement of the support, and for periodically causing the receptacle to travel at a higher speed than said support. The combination with a tank or holder for molten glass, of a machine for making glass articles comprising means for gathering a definite quantity of glass from the tank, means for subsequently shaping that gather into blowing blanks, means for blowing the blank, and means for transferring the gathered body of glass from the gathering means to the blowing means.



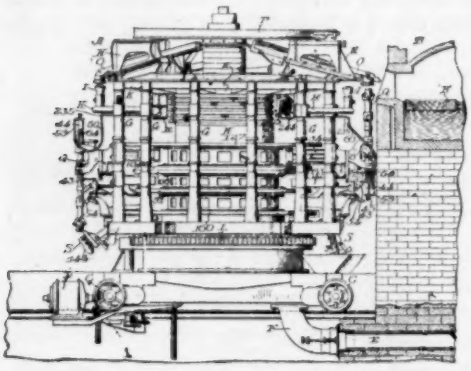
Glass-forming machine. AUGUST KADOW. U. S. 1,527,557, Feb. 24, 1925. In app. of the character described, the combination with a glass pot, of a gathering device, a marver and a mold, actuating mechanism which causes the gathering device to enter the glass in the glass pot, moves said gathering device so as to bring the glass collected thereon into contact with the marver, thereafter causes said gathering device to be swung back and forth with the glass collected thereon downward and then brings said gathering device in position to be enclosed by said mold, mechanism for causing said gathering device to revolve, and means for putting said last-mentioned mechanism out of operation while said gathering device is being swung back and forth. In app. of the character described, the combination with supporting means having a circular movement, of a gathering device mounted thereon so as to oscillate comprising an axially revoluble gathering member, means for oscillating said gathering device comprising a stationary cam and mechanism connected with said gathering device which is actuated by contact with said cam, means for revolving said gathering member comprising a circular rack and driving mechanism operated from said rack, and a stationary cam which puts said last-mentioned mechanism out of operation.





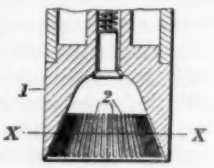
Marvering mechanism for glass-forming apparatus. AUGUST KADOW. U. S. 1,527,558, Feb.

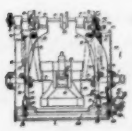
24, 1925. In a machine for producing glass articles, the combination with a blow pipe, of means for rotating the blow pipe, a marverer, and means for automatically causing the marverer to approach and recede from the gather during the marvering in a predetd. manner.



Glass-blowing mechanism. AUGUST KADOW. U. S. 1,527,559, Feb. 24, 1925. Glass working mechanism comprising a spindle adapted to receive a plastic blank in its upper end while in vertical position, means for automatically supplying puffs of compressed air to the interior of said blank while in vertical position and for relieving the air pressure in the blank between successive puffs, whereby the plastic blank is permitted to sink back upon itself, and mechanism for causing said spindle to then swing out the blank.

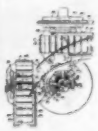
Process and apparatus for manufacture of blown articles. WILLIAM J. WOODS. U. S. 1,527,947, Feb. 24, 1925. A pressing plunger for forming glass blanks from which elec. lamp bulbs are to be blown, having an internal cup-shaped cavity, the surface of which, at points forming the surface of the blank which are subsequently to form the surface of the neck of the bulb, is serrated.



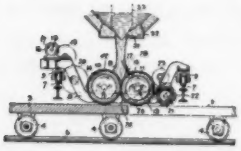


Glass-feeding machine. EVERETT O. HILLER. U. S. 1,524,638, Jan. 27, 1925. A glass feeding mach. comprising a plurality of elements coöperating to deliver mold charges of molten glass, having in combination means for independently rendering one of the elements inoperative, a cam rotating in timed relation to the operating element, and connections between the cam and the inoperative element to control its return to operative condition.

Apparatus for handling glassware. WILBUR S. MAYERS. U. S. 1,524,641, Jan. 27, 1925. In glassware handling app., a rotatably mounted table, a carrier for delivering ware to the table, a second carrier for receiving the ware from the table, one of said carriers being adjustable angularly with respect to the other, means for actuating said carriers and said table, and means for guiding the ware to and from the table to transfer it off of one carrier and on to the other.



Method and apparatus for making plate glass. FLOYD V. KESSELMAN. U. S. 1,524,179, Jan. 27, 1925. The method of making plate glass that comprises depositing a stream of molten glass of substantially uniform cross-sectional area upon a pair of coöperating rolls while said rolls are stationary, imparting relative movement as between said rolls and glass in a direction transversely of the flow of glass, and rotating said rolls to extrude the glass between them in sheet form. App. for making plate glass that comprises glass-feeding means for producing a descending mass of molten glass, a pair of coöperating rolls disposed beneath said glass-feeding means, means for producing relative movement between said glass and said rolls, thereby



distributing said glass lengthwise between said rolls, and means for rotating said rolls and for thereby extruding said glass between them in sheet form.

Borosilicate glass. SCHOTT and GEN. Brit. 219,972, Aug. 3, 1923. Optical borosilicate glasses contain K as the main alkali metal ingredient. The glass may contain B_2O_3 4–18, Al_2O_3 not more than 10, K_2O 3–19% and the remainder SiO_2. Pb oxide or BaO may be present up to 35% and the Pb may be replaced by Sb and the BaO by CaO, MgO or ZnO. (*C. A.*)

Heavy Clay Products

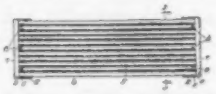
Thinning down brick wearing surfaces. WILLIS D. P. WARREN. *Eng. News-Record*, **94** [3], 116(1925).—Investigations tend to show that there is now a strong tendency to specify brick of $2^1/_2$″ to 3″ in depth in preference to brick of $3^1/_2$″ to 4″ in depth. Experience has shown that a 3-ton roller gives satisfactory results in the rolling of brick of $2^1/_2$ and 3″ in depth. These brick are widely used in the south and southwest and are being manufd. and sold in Ohio, Illinois and other north. states. It is recommended that a paving brick of $2^1/_2$″ depth be adopted for standard for all traffic except the very heaviest and that for the latter class of traffic a depth of 3″ be adopted as standard. A. H. K.

PATENTS

Removal of white excretions on brick and cement wares. Ger. Pat. 366,697. (Chem. Lab. fuer Tonindustrie.) H. SEEGER and E. CRAMER., *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*. **48**, 130–2(1924). W. S.

Bricks, plates and other molded parts. AD. KURZELOWSKY. *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*, **48**, 130–2(1924). Ger. Pat. 371,676. Mixt. of diatomaceous earth, peat, sawdust, lime, loam and hydraulic cements. The vegetable subs. are mixed with fluosilicate before adding to the other compds. W. S.

Metal pallet for brick or tile. IVAN N. DOUGHTY. U. S. 1,527,789, Feb. 24, 1925. A pallet of the class described, comprising a body member of corrugated metal, the corrugations extending longitudinally and providing reinforcement against longitudinal bending, the corrugations being formed upon smooth curves presenting rounded contact surfaces for mat. placed upon the pallet and permitting access to the air to the major portion of such surfaces, the lateral edges of the corrugated member being in a plane below the upper plane of the corrugations.



Refractories

Bauxite and aluminium. JAMES M. HILL. *Eng. Min. Jour.-Press*, **119** [3], 95 (1925).—It is estd. that the domestic production of bauxite in 1924 will be approx. 30% less than that of 1923. Supplies of bauxite were approx. 11% less than in 1923. Bauxite from South America is being used more extensively by makers of chemicals. Exports to Canada and Norway were greater during 1924. A. H. K.

Diatomite. A. W. ALLEN. *Eng. Min. Jour.-Press*, **119** [3], 96(1925).—The diatomite mining indus. showed expansion in 1924 due to a wider use of this mat. Research indicates a wider use of this mat. in the near future. A. H. K.

Refractories for boilers. L. LITINSKY. *Feuerungstech.*, **13** [7], 70 (1925).—Refrac. classified according to position in fur. as follows: (1) mat. in close contact with the fuel bed, (2) mat. in contact with flame and hot gases, (3) mat. in contact with hot gases only. Refrac. can be divided into 3 main groups: (1) silica brick (acid), (2) clay brick (basic), (3) clay brick with free quartz added (semi-basic). A comparison of the chem. compn. of these is (1) SiO_2 95–96%, Al_2O_3 2–3%, (2) SiO_2 52–60%, Al_2O_3 36–42%, (3) SiO_2 65–

80%, Al_2O_3 15–30%. Conditions encountered by boiler refrac. are (*a*) high temp., (*b*) mech. strains, (*c*) rapid temp. changes, (*d*) changes in vol., (*e*) chem. action. Refrac. used in hottest parts should withstand S. K. 31–33 and those in other parts not less than S. K. 26. Tests of the resist. to load under high temp. are valuable in detg. suitability. Mech. strength detd. by compression tests. Varies from 60–200 kg. per cm.^{2} Resist. to changes in temp. improved by use of coarse grog. Silica brick not suitable here but rather for conditions involving continuous even heat. Volume changes of the refrac. under operating conditions must be kept within limits. German Naval Specif. at one time called for a max. variation + or −2%. Silica brick tend to increase in vol. whereas clays high in Al_2O_3 tend to further shrinkage. To counteract these changes: (1) fire finished product sufficiently high, (2) calcine non-plastic ingredients at high enough temp., (3) counteract high shrinkage of basic mat. by addition of quartz which has a tendency to expand, or vice versa. In the design and construction of refrac. fur. linings the difference between temporary and permanent vol. change must be understood. Certain properties cannot be combined in one product such as d. and min. change in vol., high porosity and good condy., high porosity and high mech. strength, min. porosity and high resist. to temp. changes. Resist. to chem. action increases with lowered porosity. Mat. composed of similar ingredients such as clay and calcined clay grog more resistant than such contg. dissimilar ingredients, *i. e.* clay and quartz. Density and general physical properties more important than chem. compn. under these conditions. The action of salt fumes such as are produced in "salt glazing" was studied in its action on basic and acid refrac. linings. The latter were found more resist. probably because the protective coating of sodium silicate formed was more resistant to further action than sodium aluminum silicate. Quotes suggested specif. from Trans. Assoc. El. Power Stations, 1923, covering refrac. contg. not more than 75% SiO_2. (*a*) *Refrac. qualities.* Grade 1, brick withstanding continuous temp. of 1750–1770°C equivalent to S. K. 34/35. Grade 2, those withstanding 1690–1730°C or S. K. 28/30. Grade 3, 1630–1670°C. Material at above temp. must show no change in shape or softening under oxidizing conditions. (*b*) *Composition and structure.* Covers chem. analysis, porosity, vol. changes on refiring, resist. to slag action. Resistance to temp. changes, mech. strength (min. 130 kg. cm.^{2}), absorption (about 15% of dry wt. permissible). (*c*) *Dimensions and shape.* Sharp corners, plane surfaces, ±2% allowable variation with a max. of $^5/_8$". Warpage not over $1^1/_2$% of length. Brick must lay up with $^1/_8$" joint. (*d*) *Vol. changes.* Under no circumstances must brick increase in vol. Sample fired at cone 14 for 2 hrs. must not shrink more than 1%. F. A. W.

Classification of refractories. V. BODIN. *Ceramique*, **27**, 1–8(1925).—B. describes various methods of classifying *refrac.* His classification with respect to their resist. to load at high temps. is as follows:

Class	Temp at which the brick squatted under a load of 10 kgs. per cm^2, °C.	Class	Temp. at which the brick squatted under a load of 10 kgs. per cm.^{2}, °C.
1	1630	11	1470
2	1620	12	1460
3	1600	13	1450
4	1590	14	1440
5	1560	15	1430
6	1520	16	1420
7	1510	17	1410
8	1500	18	1400
9	1490	19	1360
10	1480		

H. G. S.

Experience with siliceous material at Leopoldau Gas Works, Vienna. PRETSCH. *Gas World.*, **82,** 70(1925).—Original setting of clay gave trouble due to fusion because of high temp. at which setting was operated. In 1914 a change to silica was made on one unit and later entire works changed. Lowering of coking time 12% and 100°C cooler flues. Shut down part of set in summer with slight cracking of walls, but expansion gradually became constant. Three thousand days was the life of the silica when in use. S. S. C.

A heat insulator and filer aid. ANON. *Chem. Met. Eng.*, **31,** 973–4(1924).—A description of the deposits and plant of the Celite Products Co. M. E. M.

Common sense and common refractories. M. C. BOOZE. *Chem. Met. Eng.*, **31,** 1003–5(1924).—No marked increase in quality can be expected in fire clay or silica refractories. The only improvement to be looked for is a greater uniformity. M. E. M.

Testing refractory materials under load. ANON. *Gas J.*, **163,** 474(1923).—Detailed description of a new app. for detg. the softening point of refractory materials under load, and also automatically and graphically recording the thermal expansion before the softening point is reached, and the subsequent contraction or compression. J. L. W. (*C. A.*)

The addition of chromium oxide to silica bricks. STEN SANDLUND. *Jernkontorets annaler* (Sweden), **1923,** 45–52.—S. has tested a method suggested by Dornhecker for increasing the resistance of silica brick to the corrosive action of FeO-bearing slags by adding Cr_2O_3 to the brick. A protecting layer of the highly refractory Cr spinel, $FeO.Cr_2O_3$, is supposed to be formed at the contact between the brick and the slag. In hand-made SiO_2 pots, fired at 1450°, slags of various compns. were melted at temps. of 1550–1600°. Charges of 10 g. were used. The melting period was 40 min. The compns. of the resulting melts are given. Cr was not found in any of the melts, which shows that Cr_2O_3 does not react to form a fusible compd. An increase from 2 to 5% of Cr_2O_3 in the SiO_2 pots has only a small influence on their resistance to corrosion. (*C. A.*)

PATENTS

High refractories and other ceramic products. A. BIGOT. Ger. Pat. 379,098. *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*, **48,** 130–2(1924). W. S.

High refractories. (A.-G. Hannover.) Ger. Pat., 371,675. *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.*, **48,** 130–2(1924).—Substance from zirconium oxide, silicon carbide and quartz. W. S.

Chamotte retort with internal protective layer and curved wall. STETTINER CHAMOTTE FABRIK A. G. Ger Pat. 368,454. *Chem. Tech. Uebersicht*, 192, *Chem. Zeit.* **48,** 130–2(1924). W. S.

Basic refractory material and method of making the same. ARTHUR LEE BROWNE. U. S. 1,527,347, Feb. 24, 1925. A basic refrac. mat. for use in lining fur. consisting of the product formed by heating a mixt. of dolomitic limestone, 2.5% to 5% oxide of iron, and 1.5% to 2% feldspar, to a temp. above the mtg. point of feldspar.

Refractory product and method of producing same. HARRISON P. HOOD. U. S. 1,527,874, Feb. 24, 1925. In the manuf. of refrac. products from sillimanite, the method which comprises steps of reducing the sillimanite to a fine powder, then mixing with water to form a paste, and then shaping and firing to cause a sintering of the material.

Synthetic refractory material. JAMES F. MOLLEN AND WALTER W. PATNOE. U. S. 1,525,655, Feb. 10, 1925. A refrac. mat. suitable for fur. linings and the like, consisting of the calcination product of raw dolomite admixed with a small percentage of argillaceous matter together with a small percentage of common salt, such mat. being

in the form of heat-compacted masses of desired shape and size substantially clean and free from dust directly as made and having approximately the following percentage compn., *viz.*, lime and magnesia together 85 and argillaceous matter 14, the salt being substantially eliminated incidentally to calcination of the raw ingredients.

Fused ore of chromium oxide and method of making the same. MINER L. HARTMANN. U. S. 1,524,030, Jan. 27, 1925. The process of producing a refrac. article, comprising fusing chromium oxide ore and shaping the article from the fused ore.

Refractory material. JAMES E. SHEAFFER. U. S. 1,525,328, Feb. 3, 1925. A refrac. made from powdered calcined magnesite and lignin liquor.

White Ware

The production of porcelain for electrical insulation. FRANK H. RIDDLE. *J. A. I. E. E.*, **42** [4], 343–6(1923).—Pt. 1. This paper deals with the history of porcelain and its definition. Low fire porcelain is an agglomerate of clay and quartz held together in a matrix of molten feldspar. At the temp. to which transmission porcelain is fired (1350°C), the quartz is markedly dissolved and the clay substance dissociates with the formation of sillimanite. *Ibid.*, **42** [5], 540–3(1923).—Pt. 2. This paper deals with ceramic raw mats., chiefly clays, quartz and feldspar, and describes the occurrence and properties of the same. Other mats. may be substituted for quartz or feldspar. *Ibid.*, **42** [6], 631–5(1923).—Pt. 3. Testing and specif. of raw mats. are discussed in this paper. The chief properties necessary for a satisfactory elec. porcelain are, d., dielec. resist., and mechanical strength. No one raw mat. possesses all. Proper blending is necessary. Glazes must be adjusted to the various types of porcelain. *Ibid.*, **42** [7], 743–7(1923).—Pt. 4. This paper deals with mfg. methods. Uniformity, grain size, and water content are of great importance in prepg. the body. *Ibid.*, **42** [8], 858–63(1923).—Pt. 5. Forming the plastic clay body into the finished insulator shape prior to firing to vitrification is of great importance. Drying and glazing are also discussed. *Ibid.*, **42** [9], 988–94(1923).—Pt. 6. This paper deals with the firing of elec. porcelain. Elec. porcelains have an extremely narrow firing range. Periodic and continuous kilns are described. The Dressler continuous is economical and efficient for this type of work. *Ibid.*, **42** [10], 1097–1102(1923).—Pt. 7. This paper describes tests for detg. the porosity, mech. strength and elec. properties of insulation porcelains. The value and use of the microscope as an aid in the study of the quality and structure of porcelain is discussed. The effect of quartz inversions and other temp. reactions can also be detd. with the microscope. H. G. F.

New decorating kiln produces exceptional results. ELMER C. COOK. *Fuels and Fur.*, **3**, 17–20(1925).—A car tunnel kiln, 171 ft. long, with full complement of automatic control equipment has a capacity of 4000 doz. of china ware per 24 hrs., with a fuel consumption of 250 gal. of oil. High quality product is attributed to the fact that the soaking period charac. of the periodic kiln is eliminated. The kiln may be shut down over holidays without great loss, as it can be brought back to operating heat within about 4 hrs. W. E. R.

Equipment and Apparatus

Thermoelectric pyrometers for the pottery. WILLIAM PRINTZ. *Fuels and Fur.*, **2**, 1279–80(1924).—Pyrometers permit close watch of the firing and indicate and record ht. progression, resulting in fuel economy and increased production by shortening firing time. To give complete information the installation should consist of 3 or 4 couples located in different parts of each kiln. W. E. R.

The origin of the Hardinge mill. J. C. FARRANT. *Chem. Age.*, **12**, 98(1925).—

The cause for the producing of the present mill was from trouble in trying to produce fine mat. at a rapid rate in a copper plant in Colorado in 1906. The idea was obtained by the segregating of fines and coarse sizes on a dump conical in shape. The first installation produced 96 T. per 24 hrs. using 12.3 h. p. The screen analyses and power data obtained on other installations are given. S. S. C.

Regrading the relation between rate of flow of Klever's rapid viscosimeter and Engler's viscosimeter. HELMUT W. KLEVER, ROBT. BILFINGER AND KARL MAUCH. *Z. f. angew. Chemie*, **37**, 693–5(1924). W. S.

Crushing and grinding. I. S. G. URE. *Chemistry & Industry*, **43**, 1144–52(1924).—A mathematical analysis of the power required for crushing is given. A very complete description is given of jaw, disk and gyratory crushers. L. A. P. (*C. A.*)

Automatic apparatus for metering and sampling fluids. KOCH. *Z. Zuckerind. cechoslov. Rep.*, **48**, 335–7(1924).—The app. rotates about the shaft *A*. *C* is a stationary delivery tube bringing in the liquid to be measured. An inner drum is divided into 3 compartments 1, 2, 3, connected to each other by the openings e_1, e_2, e_3, and to the chambers I, II, III, by the openings b_1, b_2, b_3. Liquid flows from *C* into 1 and thence through b_1 into I. When I is completely filled, liquid backs up in 1, and flows through e_2 and b_2 into II. As liquid collects in II the center of gravity of the app. changes and it rotates as shown by the arrow, discharging at f_1. A counter on the shaft gives readings accurate to 0.02%. The sampling device consists of 3 small chambers fastened to one end of the drum, filling from the chambers I, II and III, and discharging to a launder as the app. rotates. W. L. B. (*C. A.*)

Apparatus for the determination of melting and freezing points of pure substances and of eutectic mixtures. E. W. WASHBURN. *Ind. Eng. Chem.*, **16**, 275(1924).—The app. consists essentially in a Dewar flask of Pyrex glass, the inner tube of which is constricted at the bottom to form a receptacle for the substance being studied and the bulb of the thermometer. It is designed for the method of plotting the time-temp. curve while passing through the m. p. in either direction. F. L. B. (*C. A.*)

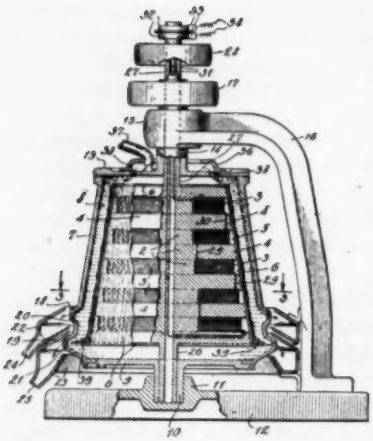
A new micro-melting point apparatus. J. F. CLEVENGER. *Ind. Eng. Chem.*, **16**, 854–5(1924).—Details of construction and drawings are given of an elec. heated app. designed for attachment to a microscope stage, by which can be detd. accurately the m. p. of a single minute crystal. Details of operation, and also several results, are given. M. p. up to 400° can be detd. E. R. G. A. (*C. A.*)

Filter plate of great strength. ANON. *Chem. Met. Eng.*, **31**, 509(1924).—A description of the properties (strength, soly. in various aqueous solns., etc.) of aluminous filter plates mfd. by the Norton Co. E. G. R. A. (*C. A.*)

PATENTS

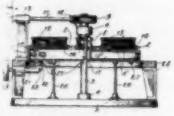
Humidity control of drying kilns. A. E. KRICK. U. S. 1,513,727, Oct. 28, 1924. In a kiln for drying lumber or other materials, automatic devices are arranged to produce alternate lowerings and raisings of the relative humidity of the air in the kiln. (*C. A.*)

Rapid viscosimeter. H. W. KLEVER. Ger. Pat. 351,027. (Communication of Chem. Tech. Institute of Tech. Univ., Karlsruhe.) *Z. f. angew. Chem.*, **37**, 696, 861 (1924). The app. consists in its main parts of a htg. bath, an oil reservoir and a measure pipette. The oil reservoir is immersed into the bath and held in place by a brass cover mounted on a stand. The pipette is of glass with capillary tube of brass cemented on. Each instrument is calibrated individually and furnished with a curve by which the Engler values (detd. by Engler viscosimeter) can be obtained in a short time. A table shows viscosities of 7 different oils in °E (deg. Engler) at various temps. detd. with the rapid viscosimeter. The instrument also can be employed for measg. viscosities of porcelain slips. W. S.

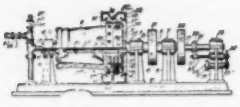


Magnetic centrifugal separator. ORRIN B. PECK, JR. U. S. 1,527,070, Feb. 17, 1925. In a magnetic centrifugal separator the combination of a rotatable electromagnet, a surrounding rotatable vessel with a sepg. channel between the vessel and the magnet, encircling the latter, adapted to hold liquid, and means for rotating the vessel and magnet separately, substantially as described.

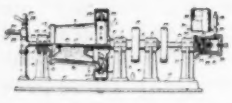
Magnetic separator. ORRIN B. PECK, JR. U. S. 1,527,071, Feb. 17, 1925. In a magnetic separator the combination of a supporting member adapted to be rotated in a horizontal plane, an electromagnet thereon adapted to be carried by said member, a vibratable liquid and material container located below said magnets with its top side below and adjacent to the path of travel of the magnet, means for revolving the supporting member and means for vibrating the container, substantially as described.

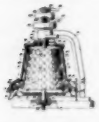


Centrifugal concentrator. ORRIN B. PECK, JR. U. S. 1,527,072, Feb. 17, 1925. In a centrifugal concentrator, the combination of a rotatable concentrating vessel, a rotatable core within the vessel, an attached head to said vessel provided with normally open concentrate discharge means adapted to be actuated to closure by relatively highly developed centrifugal force, and means for rotating the vessel and head, substantially as described.

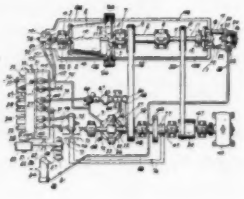


Centrifugal concentrator. ORRIN B. PECK, JR. U. S. 1,527,073, Feb. 17, 1925. In a centrifugal concentrator adapted to operate in successive cycles, each embodying a period of separation and accumulation of a bed of concentrates, and a period of discharging said concentrates, the combination of a rotatable tapering concentrating vessel, a relatively differentially rotatable core within said vessel adapted to be forced endways during operation in part by liquid pressure within the feed end of the vessel, means for supporting and rotating said core, and yieldable means in axial extension with said core for resisting longitudinal movement of the core in direction from the feed end of the vessel, substantially as described.





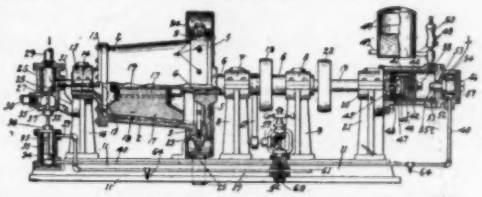
Process or method of and apparatus for magnetic centrifugal separation. ORRIN B. PECK, JR. U. S. 1,527,069, Feb. 17, 1925. The process of separating mixed magnetic and non-magnetic solids while pulverized and mixed with liquid, which consists in simultaneously subjecting such mixture to the opposing action of centrifugal and magnetic forces in a liquid filled channel under confined pressure, and to washing force of such liquid, substantially as described.



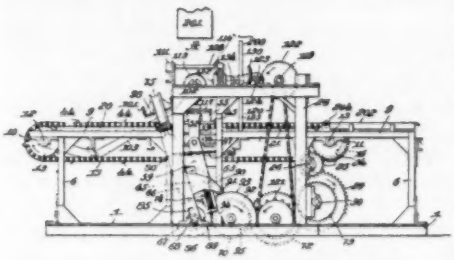
Plant for centrifugal concentration of ores and like materials. ORRIN B. PECK, JR. U. S. 1,527,074, Feb. 17, 1925. In a concentrating plant for treatment of finely divided mat. having constituents of different degrees of sp. gr., while mixed with liquid, the combination of a concg. element embodying a rotatable concentrating vessel adapted

to operate in cycles, each embracing a period of collecting a quantity of heavier constituents at high speed and then discharging the same at relatively low speed of the vessel, and a core member adapted to operate at practically constant speed throughout said cycle, means for effecting such constant speed of the core, means for effecting such relatively high speed of the vessel, means for effecting and maintaining such low speed of the vessel without stoppage during the discharge period, and means for automatically functioning said several operations of the vessel, and core, governed in part by accretion of heavier constituents in the vessel, substantially as described.

Centrifugal concentrator. ORRIN B. PECK, JR. U. S. 1,527,075, Feb. 17, 1925. In a centrifugal concentrator the combination of a rotatable vessel, a differentially rotatable longitudinally movable core within the vessel, adapted in operation to be pressed towards the discharge end of the vessel, yieldable hydraulic means for resisting such endways pressure, means for feeding material and feeding water to said vessel at desired time, and means for hydraulically operating said feed means, substantially as described.



Apparatus useful in making plastic shapes. CHARLES L. NORTON. U. S. 1,526,364, Feb. 17, 1925. A machine of the class described comprising a conveyor for moving independent unconnected pallets, a movable mold box, means for pressing the mold box into engagement with successive pallets, and means whereby plastic material may forcibly be projected into the mold box while engaging a pallet plate, and means for positively ejecting the molded shape from the mold box.



Kilns, Furnaces, Fuels, and Combustion

Producer gas for glass tanks. BJARNE SCHIELDROP. *Fuels and Fur.*, **2**, 945–7 (1924).—The coal used and the operation of gas producers should be uniform at all times, insuring a regular supply of gas of constant compn. and press. W. E. R.

Relation of fuel oil system to grade of oil used. LINCOLN T. BRADLEY. *Fuels and Fur.*, **2**, 971–2(1924).—Fuel oil systems should be capable of burning heavy oil. Economy demands that specif. for fuel oil should not be more strict than the requirements of the plant. Maintenance of oil burners in good condition is of importance. W. E. R.

Combustion devices for gaseous fuels. W. TRINKS. *Fuels and Fur.*, **2**, 1035–8, 1157–60, 1249–52(1924); **3**, 35–8(1925).—Burners are classified: A, gas and air are mixed in the fur.; B, gas and air are mixed outside the fur.; C, gas is mixed with some air outside of the combustion chamber, the rest of the air is mixed in the fur. The selection of the proper burner depends upon the kind of gas used, the fur. temp., the vol. of the fur. combustion chamber and the character of the flame desired. W. E. R.

Auxiliary equipment for oil burning. KESTER MILLER. *Fuels and Fur.*, **2**, 1047–54, 1149–54, 1261–7(1924); **3**, 139–46(1925).—Air compressing app. is grouped in 4 broad divisions: (1) Fans or centrifugal blowers, supplying air at pressures up to 24 oz. per sq. in.; (2) turbo-blowers or turbo-compressors, air from $^3/_4$ to 4 lbs. per sq. in.; (3)

positive press. rotary blowers, air normally from 3/4 to 4 lbs., 10 lbs. per sq. in. max.; (4) piston compressors, for pressures from 20 lbs. per sq. in. upward. Characteristic curves for the different types are given. The ease of regulation of fans or centrifugal blowers is of special advantage in the application of temp. control equipment. Fans and turbo-blowers possess the advantage of compactness and steady flow of air. Positive press. blowers give a pulsating flow of air which must be equalized in a tank to provide the steady flow requisite to the opern. of oil burners; their efficiency is higher than that of other types of blowers for their particular press. range. Positive press. blowers of a special type, with liquid seal, deliver a steady flow of air and do not require air tanks. The piston compressor is used for supplying atomizing air at pressures of from 20 lbs. per sq. in. to 100 lbs. per sq. in. or over. The single stage compressor is most suitable for pressures from 15 to 60 lbs. per sq. in.; the 2-stage from 100 to 300 lbs. per sq. in.; and 3- and 4-stage types for pressures higher than any used in oil atomizing. For the range between 60 and 100 lbs. per sq. in. either single or 2-stage compression can be used, depending on capacity, cost of power, and altitude. The discharge from compressors is pulsating, so that a tank is required. The vol. of the tank in cu. ft. should be about 1/5 of the piston displacement of the compressor in cu. ft. per min.

W. E. R.

Storage and handling of fuel oil. C. G. SHEFFIELD AND H. H. FLEMING. *Fuels and Fur.*, **2**, 1255–6(1924).—Part of a paper read before the A. S. M. E., Dec., 1924. Steel cylindrical tanks, usually vertical, are most satisfactory for fuel oil storage in indus. plants. Underground storage has the advantage of low fire hazard but a steel tank should never be placed underground where there is any danger of the water table being above the bottom of the tank. Storage capacity depends upon max. rate of consumption. Capacity for only slightly more than a tank car is inadvisable. Pipe lines from tank to burners should be as short as possible. A "swing suction" is best method for removal of oil from tanks. Heavy oils are heated by a steam coil in the bottom of a small tank or a steam coil around the suction pipe of a large tank.

W. E. R.

Hazards of industrial oil burning. H. E. NEWELL. *Fuels and Fur.*, **2**, 1257–8 (1924).—Part of a paper read before the A. S. M. E., Dec., 1924. Fuel oil storage tanks should be situated and erected in such a manner as to involve the least fire hazard.

W. E. R.

Excess air and the extra cost of fuel. W. F. SCHAPHORST. *Eng. Min. Jour.-Press*, **119** [4], 169–70(1925).—A simple chart is given by means of which the extra cost of fuel involved, by using excess air, is detd. To det. the min. wt. of air required for combustion it is necessary to know, approx. at least, the parts by wt. of carbon, hydrogen and oxygen in one lb. of fuel. To compute the number of pounds of air required per pound of fuel, divide the wt. of oxygen per lb. of fuel by 8 and subtract the result from the wt. of hydrogen in one pound of the fuel. Multiply the difference by 3 Add the product to the wt. of carbon in each lb. of fuel, then multiply by 11.6. The result is the number of lbs. of air required per lb. of fuel. To compute the expense involved by the use of excess air per year mathematically rather than by the use of the chart, subtract the temp. of the air passing into the fur. from the chimney-gas temp. and multiply by 1.05. Then multiply the result by the number of pounds of excess air used per hour. Then multiply that by the cost of fuel per ton. Then divide by the B. t. u. value per lb. of fuel.

A. H. K.

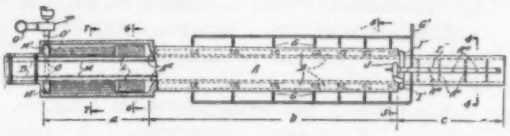
Blue water gas offers industrial fuel economies. D. J. DEMOREST. *Chem. Met. Eng.*, **31**, 887–90(1924).—Blue water gas is free from tar and soot, burns without smoke or soot, and has a high flame temp. Where a large number of small heating operns. are required in one neighborhood, and a central generator can be installed and gas piped

under press. to various points, blue water gas can compete with producer gas. With coke at $10.00 per ton, this gas costs about $0.27 per 1000 cu. ft. Its method of manuf. is outlined. M. E. M.

Firing brick and tile, practical ways of reducing the cost. W. D. RICHARDSON. *Contract Rec. and Eng. Rev.*, **39**, 77(1925).—At the 23rd Annual meeting of the Canadian Natl. Clay Products Assn. R. outlined 6 methods by which clay products may be mfd. more cheaply: (1) By better methods of firing and managing present kilns. (2) By using a more economical fuel in firing present kilns. (3) By more efficient and less wasteful furnaces on present kilns. (4) By employing forced or induced draft on present kilns. (5) By a regenerative system of present kilns. (6) By building a more efficient and economical type of kiln. O. P. R. O.

PATENTS

Open-fire tunnel kiln. PHILIP D'HUC DRESSLER. U. S. 1,525,232, Feb. 3, 1925. The method of maintaining a graduated temperature along the length of an elongated heating zone of a tunnel kiln while minimizing temperature variations in any transverse plane through said zone, which consists in introducing heating gases into the kiln at the bottom of the pathway through the kiln for the goods along the length of said zone in such volume and at such temperatures and under such conditions of pressure and velocity that the heating gases thus introduced will flow mainly upward through said pathway from the points of gas introduction to the top of the pathway, and will impart the major portion of their available heat to the goods in their upward movement through the goods pathway.



Tunnel kiln. WINFIELD E. HINSDALE. U. S. 1,525,130, Feb. 3, 1925. A tunnel kiln having a continuous tunnel chamber and successive cars traveling therethrough, the kiln comprising a heating zone, a torrid zone, and a cooling zone, having end doors, and the inlet and outlet portions of the tunnel chamber formed of minimum cross-section closely approximating that of the carloads of stacked wares under treatment, whereby to substantially close the end portions of the tunnel and prevent inflow of air toward the torrid zone, and the firing chamber at the torrid zone of greater cross-section, and having a dead air insulation surrounding the tunnel chamber, whereby when once heated to operative incandescence the kiln conserves heat and permits economic operation, and means for absorbing heat radiated from the wares traversing the cooling zone, conveying such heat past the firing chamber, and radiating it in the heating zone to preheat the wares therein.

Geology

Bentonite, its occurrences, properties and uses. HUGH S. SPENCE. Rept. to Mines Branch, Ottawa, Can. Abstracted in *Can. Chem. & Met.*, 9 [2], 39(1925).—So far no attempt has been made to develop any of the Canadian bentonite deposits. Considering nearness to railway transportation the deposits showing the most promise for immediate cheap development are those at Rosedale, Alberta; Knollys, Saskatchewan and Princeton, B. C. At Rosedale a seam 6 to 10 in. thick occurs in a coal mine. At Knollys an 8 ft. bed of bentonite is exposed about $^1/_2$ mile from a railway. At Princeton B. C., 2 thin bentonite beds are found in a coal mine and several promising outcrops have been noted nearby. American production is described. Nine classes of possible uses for bentonite are suggested. F. G. J.

Cordierite, anthophyllite mineralization at Blue Hill, Maine. W. LINDGREN. *Proc. Nat. Acad. Sci.*, **11,** 1–4(1925).—A type of mineralization now found for the first time in America, but entirely similar to described occurrences from Fenno-Scandia. The ores are a replacement of the schist in which they form lenticular bodies. They are caused by emanations from the granite outcrops in the vicinity, the vapors contg. Fe, Mg, S and SiO_2. Such magnesian metasomatism can probably only be carried out at very high temps. H. H. S.

Gel replacement, a new aspect of metasomatism. W. LINDGREN. *Proc. Nat. Acad. Sci.*, **11,** 5–11(1925).—Replacement of one mineral by another in the colloid state as gel happens in solid rocks more frequently than has been supposed. The gel may be converted later into a cryst. aggregate, becoming a metacolloid. Gel replacement operates at low temps. probably not above 300°C. Solns. or sols moving in capillary or subcapillary openings form the medium of attack and pptn. The author deals with replacement by silica gel, by sulphides, arsenides and sulpharsenides. H. H. S.

Bentonite and its uses. ANON. *Chem. Met. Eng.*, **32,** 59(1925).—Lists producers of this material in U. S. and Can., and gives an outline of possible uses. M. E. M.

Silica. HJALMAR E. SKOUGOR. *Eng. Min. Jour.-Press*, **119** [3], 97(1925).—Production of silica was stimulated during 1924. The silica industry should better itself by the operators availing themselves of various investigations enumerated which are concerned with the betterment of the industry. A. H. K.

Kaolin. R. T. VANDERBILT CO. *Eng. Min. Jour.-Press*, **119** [3], 97(1925).—Indications are that the domestic kaolin business during 1924 will far exceed that of 1923. Besides the marked improvement in vol., considerable activity in tech. developments connected with its use has occurred, especially in the pottery trade. Tests have proved to the potter that he can use large quantities of domestic kaolins to good advantage. The present indications point to the use of considerable quantities of kaolin in 1925 in the pottery trade where little or none has been used in the past. A. H. K.

Feldspar. FRANK P. KNIGHT. *Eng. Min. Jour.-Press*, **119** [3], 97–8(1925).—During 1924 the outstanding features in the feldspar indus. were a marked expansion in mill capacity, a finer grinding of the finished product, an increase in cost of the crude material and a decrease in the selling price of the finished product. In treating feldspar, the continuous grinding and air-sepn. process has become more firmly established. The indus. as a whole is facing a period of readjustment. A. H. K.

Australian clays in the manufacture of white pottery wares. R. C. CALLISTER. *Australia Inst. Sci. Ind. Bull.*, No. **27,** 87 pp.(1924).—Australia imports $3,500,000 worth of pottery annually. Raw materials are available to produce most of this in Australia. A clay-washing plant is the greatest need. In expts. both electroösmosis and elutriation were tried with about equal results. Very careful purification is necessary and the firing must be approx. neutral. Neutralizing the creamy color with 0.0015% pptd. Co stain (0.2 g. $CoSO_4.7H_2O$ to 0.1 g. Na_2CO_3) gave much whiter ware. Adding 0.1% dextrin or casein during the maturing period greatly improved the working properties. The Co stain was not effective when the $Fe_2O_3 + TiO_2$ exceeded 1%. Not over 10% ball clay must be used in semi-porcelains (adsorption about 6%) or the color will be too dark. C. H. K. (*C. A.*)

The world's biggest borax deposits. W. F. FOSHAG. *Eng. Mining Jour.-Press*, **118,** 419–21(1924).—The mineral colemanite supplies almost the total production of borax ores at present. Ulexite is an associated mineral, with other rarer borates found occasionally. Five principal localities have produced colemanite—Lockwood Valley, Lang, Borate, and Death Valley region, all in Calif., and Muddy Mountains, Clark Co., Nev. The ore occurs as irregular masses in soft shales associated with fine-grained sandstone, thin beds of cherty limestone, and volcanic flows. W. N. N. (*C. A.*)

Chemistry and Physics

A delicate method of detecting cobalt. S. J. JINDAL. *Chem. News*, **130**, 34 (1925).—Na_2SiO_3 is added to soln. of Co salt producing blue ppt., addn. in excess gives blue soln. Acidity causes color to vanish. Br_2 water is added to silicate soln. giving black color. 0.000039 gr. of Co in 5 cc. can be detected. When Co is mixed with Ni, Ba, NH_3, Ca salts the Co still showed the black. H_2O_2, Cl_2 water may be used in place of Br_2. H_2O_2 causes a greenish yellow color. Br_2 is recommended. The chemistry of the reaction is discussed. S. S. C.

Table of atomic weights (O = 16.000) of the chemical elements issued by the International Union of Pure and Applied Chemistry, 1925. ANON. *J. Soc. Chem. Ind.*, **44**, 138(1925).—

	Symbol	Atomic number	Atomic weight		Symbol	Atomic number	Atomic weight
Aluminium	Al	13	26.97	Lead	Pb	82	207.20
Antimony	Sb	51	121.77	Lithium	Li	3	6.940
Argon	A(Ar)	18	39.91	Lutecium	Lu	71	175.0
Arsenic	As	33	74.96	Magnesium	Mg	12	24.32
Barium	Ba	56	137.37	Manganese	Mn	25	54.93
Beryllium	Be	4	9.02	Mercury	Hg	80	200.61
Glucimium	Gl			Molybdenum	Mo	42	96.0
Bismuth	Bi	83	209.00	Neodymium	Nd	60	144.27
Boron	B	5	10.82	Neon	Ne	10	20.2
Bromine	Br	35	79.916	Nickel	Ni	28	58.69
Cadmium	Cd	48	112.41	Nitrogen	N	7	14.008
Caesium	Cs	55	132.81	Osmium	Os	76	190.8
Calcium	Ca	20	40.07	Oxygen	O	8	16.000
Carbon	C	6	12.000	Palladium	Pd	46	106.7
Cerium	Ce	58	140.25	Phosphorus	P	15	31.027
Chlorine	Cl	17	35.457	Platinum	Pt	78	195.23
Chromium	Cr	24	52.01	Potassium	K	19	39.096
Cobalt	Co	27	58.94	Praseodymium	Pr	59	140.92
Columbium	Cb	41	93.1	Radium	Ra	88	225.95
Niobium	Nb			Radon	Rn	86	222.
Copper	Cu	29	63.57	Rhodium	Rh	45	102.91
Dysprosium	Dy	66	162.52	Rubidium	Rb	37	85.44
Erbium	Er	68	167.7	Ruthenium	Ru	44	101.7
Europium	Eu	63	152.0	Samarium	Sm	62	150.43
Fluorine	F	9	19.00	Scandium	Sc	21	45.10
Gadolinium	Gd	64	157.26	Selenium	Se	34	79.2
Gallium	Ga	31	69.72	Silicon	Si	14	28.06
Germanium	Ge	32	72.60	Silver	Ag	47	107.880
Gold	Au	79	197.2	Sodium	Na	11	22.997
Helium	He	2	4.00	Strontium	Sr	38	87.63
Holmium	Ho	67	163.4	Sulphur	S	16	32.064
Hydrogen	H	1	1.008	Tantalum	Ta	73	181.5
Indium	In	49	114.8	Tellurium	Te	52	127.5
Iodine	I(J)	53	126.932	Terbium	Tb	65	159.2
Iridium	Ir	77	193.1	Thallium	Tl	81	204.39
Iron	Fe	26	55.84	Thorium	Th	90	232.15
Krypton	Kr	36	82.9	Thulium	Tm	69	169.4
Lanthanum	La	57	138.90	Tin	Sn	50	118.70

TABLE (*Continued*)

	Symbol	Atomic number	Atomic weight		Symbol	Atomic number	Atomic weight
Titanium	Ti	22	48.1	Xenon	Xe	54	130.2
Tungsten / Wolfram	W	74	184.0	Ytterbium	Yb	70	173.6
				Yttrium	Y	39	88.9
Uranium	U	92	238.17	Zinc	Zn	30	65.38
Vanadium	V	23	50.96	Zirconium	Zr	40	91.0

The elements of atomic numbers 43, 61, 72, 75, 84, 85, 87, 89, and 91 have not been discovered. H. H. S.

The behavior of sulphur and amorphous carbon at high temperatures. III. J. P. WIBAUT AND G. LA BASTIDE. *Rec. trav. chim.*, **43**, 731–56(1924).—In a previous paper W. (*C. A.*, **16**, 2648) proved that when pure amorphous C is heated in an atm. of S vapor a "sulfurous carbon" is formed, contg. about 2% S, which can neither be extd. with solvents nor sepd. by heating in a vacuum at 1000°. From this it was concluded that this S was chemically combined with the C. The purpose of that work was to det. the conditions under which the "sulfurous carbons" that occur in gas coke or in metallurgical coke are formed. For that reason the C was exposed to S vapor at high temps. In continuing the expts. the influence of the temp. and duration of the heating on the reaction between S and C was studied. Since it was desired to work with finely divided amorphous C a series of expts. was made by heating mixts. of this with S in closed tubes at definite temps. Afterwards the contents were extd. with CS_2 and PhMe until no more S was removed. The residue was a carbonaceous substance resembling amorphous C with 10–25% S, depending on the temp. and duration of the heating. When amorphous C is heated with S at 600° for a long time in a closed tube, substances resembling the C used but contg. 18–25% S are formed. This S is combined with the C in some way, since by the action of solvents like PhMe, CS_2 and SCl the S content remains unaltered in some cases while in other expts. a small decrease was noticed. By heating these substances to 600° in a vacuum the greater part of the combined S is eliminated. The process thus seems reversible. It is possible that part of the S which seps. in a vacuum is combined in the surface layer of the C (adsorption) or is present in the C in solid soln. However, if this is the case it is hard to understand why this S cannot be extd. with solvents. While the greater part of the S in the "sulfurous carbons" with a high S content is rather closely combined a smaller portion is held in some other manner but more firmly, for during the heating in a vacuum small amts. of CS_2 are formed. Special expts. indicate that the CS_2 formed at 600° was not formed by the action of primarily sepd. S vapor in the C. The simplest interpretation of these facts is to assume that part of the S is combined with the C by valency forces. The CS_2 would be produced by the decompn. of such a C-S complex. Nothing definite can be said concerning the characteristics of these C-S compds. Finally a part of the S remains firmly combined with the C, since after heating at 1100° in a vacuum at 0.5 mm. "sulfurous carbons" remain contg. about 2.8% S. Nearly the whole of this combined S is eliminated as H_2S by the action of H_2 on these carbons at 500–700°. In the previous paper W. (*loc. cit.*) pointed out the analogy between the behavior of amorphous C toward S, and its behavior toward O as shown by the expts. of Rhead and Wheeler (*C. A.*, **6**, 2567; **7**, 2362) and Lowry and Hulett (*C. A.*, **14**, 2435). The facts described in this paper seem to corroborate this analogy. Finely divided artificial graphite fixes little or no S. Expts. with different specimens of amorphous C gave different results as to the quantity of S that is fixed. The samples of C used contained 0.2–0.5% H. If the action of S consisted in replacing this H, carbons with about 3% S could be produced. Besides the sulfurous carbons when heated *in vacuo* still give some H_2S so that not all

the H is displaced in carbons contg. 25% S. Mixter's (*Am. J. Sci.*, **45** [3], 373(1893)) conclusion that amorphous C fixes little S while "soft sugar charcoal," still contg. much H and O, can fix large amts. of S is not correct. W. and B. proved that amorphous C can fix large amts. of C. Expts. have not been made as yet with diamond dust. The work is being continued. E. J. W. (*C. A.*)

Composition of melilite. A. N. WINCHELL. *Am. J. Sci.*, **8**, 375–84(1924).—The dominant mols. in melilite are $Ca_2Al_2SiO_7$ (gehlenite) and $Ca_2MgSi_2O_7$ (åkermanite). The grossularite and andradite mols., which have been assumed in some melilites, are not similar to the chief components of that group and probably cannot enter the mineral. The assumed sarcolite "double mol.," $(9Ca.Na_2)_3Al_2Si_3O_{12}$, is not an entity, being actually composed of 60.65% gehlenite, 16.07 $Na_2Si_2O_7$, 14.87 $Ca_3Si_2O_7$ and 8.41 SiO_2. Fe'' in melilite replaces part of the Mg of åkermanite; Fe''' the Al of gehlenite; excess Ca the Mg of åkermanite. Na and K in melilite may be assigned to $Na_2Si_2O_7$ and $K_2Si_2O_7$, resp., although other mols. are possible, one of which, $NaAl_2SiO_7$, seems to be present in certain ferriferous melilites. All mols. forming part of the space-lattice of melilite are of the same type, that is, they conform to R_3O_7, in which R includes Si as well as metallic atoms. The theory that excess SiO_2 can exist in interat. spaces seems to correspond well with the known facts that the excess Si has very little effect on the *n*s., but considerable upon the sp. gr., at least in types near the compn. of åkermanite. L. W. R. (*C. A.*)

The chemical constitution of silicates. B. GOSSNER. *Centr. Mineral. Geol.*, **1924**, 97–106, 129–40.—The formula for *clinochlore* is written: $(SiO_2.2SiO_2Mg)_3\begin{matrix}AlO_2H\\MgO_2H_2\end{matrix}$. Mutual replacement to a moderate extent between SiO_2 and AlO_2H and also between AlO_2H and MgO_2H_2 enable G. to account for all the members of the chlorite group. Twenty analyses are recalcd. to illustrate this new conception. J. E. C. (*C. A.*)

The crystal habit of potash feldspars considered from a minerogenetic standpoint.—G. KALB. *Centr. Mineral. Geol.*, **1924**, 449–60.—A relationship between crystal development and temp. of formation is pointed out. J. E. G. (*C. A.*)

Some moisture relations of colloids. II. Further observations on the evaporation of water from clay and wool. E. A. FISHER. *Proc. Roy. Soc.* (London), **103A**, 664–75 (1923); cf. *C. A.*, **17**, 2466, 2528.—The study of the evapn. of H_2O from colloidal materials has been extended to kaolin and a ball clay. When the rate of evapn. is plotted against moisture content, the curve for ball clay does not show the curvature previously noted in a clay subsoil and attributed to shrinkage, although the ball clay also shrinks. This type of curvature is found only with materials which are mixts. of colloidal and non-colloidal substances, and is due to the simultaneous evapn. of imbibitional H_2O held by the colloid and of interstitial H_2O held as H_2O wedges between the soil grains. The former H_2O evaps. at a practically const. rate, while the latter evaps. at a rapidly diminishing rate. The bearing of these results on the evapn. of H_2O from wool fabrics is discussed. F. L. B. (*C. A.*)

An attempt to cheapen the production of zirconium dioxide. J. W. BAIN AND G. E. GOLLOP. *Can. Chem. Met.*, **7**, 35–8(1923).—Brazilian zirkite runs 70 to 80% ZrO_2; only 55 to 65% of the Zr is actually present as ZrO_2; the remainder is silicate. In the Florida zirconia sands there is more Zr silicate and hence these sands are harder to treat. By passing dry Cl_2 or $COCl_2$ over heated Zr-bearing ore mixed with C, $ZrCl_4$ can be volatilized and pure ZrO_2 can be prepd. therefrom. The reaction is slow; the yields for Cl_2 are far from theoretical; and the process is difficult to carry out commercially. Fusions with (*a*) NaOH, (*b*) Na_2CO_3, (*c*) niter cake and (*d*) KHF_2 are described in *C. A.*, **15**, 3952. Of the soln. methods the best employs 66° Bé. H_2SO_4. By using 2 pts. H_2SO_4 to 1 pt. ore and heating to approx. 275° for 1 hr., 1–7% of the ZrO_2 in some

Brazilian ore is brought to soln. Higher temps. and longer time did not increase the yield. The usual methods of producing a pure ZrO_2 from the H_2SO_4 soln. are too expensive for com. work. After extg. the residue with hot H_2O, the ZrO_2 can be pptd. by boiling as basic sulfate (Pugh's pat. U. S. 1,316,107). To reduce the free H_2SO_4 to approx. half that of the ZrO_2 present, addn. of (1) $CaCO_3$, (2) $CaCl_2$ and (3) $CaCO_3$ + $CaCl_2$ were tried. B.'s and G.'s expts. show that Zr is retained by the pptd. $CaSO_4$, and that great diln. is necessary to bring down the ZrO_2 in appreciable amt. by boiling. By suitably adjusting the concns. and dilg. the filtrate about 40 times before boiling, about 75% of the ZrO_2 in soln. can be pptd. The ppt. merely requires washing and ignition. One sample so obtained gave on analysis 98.6% ZrO_2. E. G. R. A. (*C. A.*)

Silicon in aluminium-silicon alloys. J. D. GAT. *Ind. Eng. Chem.*, **16**, 959–60 (1924).—Graphitic Si is more or less oxidized during the treatment of Al alloys with acid and subsequent heating to dehydrate SiO_2. To det. Si in an alloy, treat 0.5 g. in a 50 cc. Fe crucible with 2 g. NaOH and 1 cc. water. When the action abates, add 9 cc. of water and heat on the hot plate. Transfer finally to an evapg. dish and rinse the crucible with water, then with 35 cc. of acid mixt. (300 cc. concd. H_2SO_4, 300 cc. water, 300 cc. concd. HCl and 100 cc. concd. HNO_3) and then with water. Evap. to dryness and fume strongly for 5 min. Cool, take up with 50 cc. of 3 *N* H_2SO_4 and boil. Filter, ignite, weigh and test the purity of the SiO_2 with HF. W. T. H. (*C. A.*)

PATENTS

Base-exchange silicate and process of preparing same. YONG K. LEE. U. S. 1,527,199, Feb. 24, 1925. The process of prepg. a base exchange silicate, which comprises forming a coating upon carrier particles having base exchange capacity, from sodium silicate and aluminum sulphate and baking, which coating will increase base exchange capacity of such particles.

Process of making zirconium oxide. HUGH S. COOPER. U. S. 1,527,470, Feb. 24, 1925. Process of prepg. coarsely powdered zircon for decomposition by fused caustic soda which comprises heating the zircon to a red heat and quenching it.

Purification of clay. WILLIAM FELDENHEIMER and WALTER WILLIAM PLOWMAN. U. S. 1,526,971, Feb. 17, 1925. The process for the purification of clay which comprises effecting peptonization of the clay with a dilute aqueous solution of caustic alkali and alkaline-earth hydrate.

Vitreous material. FREDERICK G. KEYES and CHARLES A. KRAUS. U. S 1,526,423, Feb. 17, 1925. A vitreous material composed of silica qualified by boric anhydride.

Manufacture of chromates. LOUIS CHARLES DREFAHL. U. S. 1,526,325, Feb. 17, 1925. Process of oxidizing chromium compounds which comprises blast roasting a mixture of the same with a carbonaceous fuel and a compound of an alkali forming metal at a temperature in the neighborhood of 1500°F.

General

Ceramic engineering courses in Canadian universities. ANON. *Contract Rec. and Eng. Rev.*, **39**, 86(1925).—Clay products manufacturers, individually and through the Canadian National Clay Products Association, have endeavored for years to establish courses in ceram. eng. in Canadian univ., with result that the Univ. of Sask. had its 1st graduation of ceramic engineers last year; and the establishment of a ceram. course in Univ. of Toronto now seems assured. To the late JOSEPH KEELE, the clay products manufacturers of Canada acknowledge their everlasting gratitude for his activity in promoting these ceram. courses. O. P. R. O.

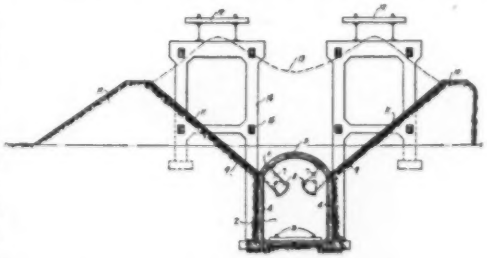
Marketing of high grade clays. FELIX E. WORMSER. *Eng. Min. Jour.-Press*, **119** [4], 163–8(1925).—Each clay has its own marketing problems. The phys. prop-

erties of the clay to be marketed should be carefully looked into. It should be subjected to tests to determine its plasticity, shrinkage, color, fineness and its behavior under firing at various temps. With this information it can be stated as to what use the clay can be put. It is a difficult matter to put a new clay on the market as the consumers, through long association with clays from certain localities, are reluctant to make any change. Also, domestic clays have strong competition from Europe, so much so that a tariff on foreign clays is enforced. Bentonite is coming into wide use as a clay. It has the property, when moistened, of absorbing about three times its weight of water. It is used chiefly as a cosmetic and in paper manufacture. A table is given showing detailed amounts of clay used in different consuming branches of indus., together with data on the classification and physical properties of clays. A. H. K.

Tests of a powdered-coal plant. H. KREISINGER, J. BLIZARD, C. E. AUGUSTINE AND B. J. CROSS. Bur. of Mines, *Tech. Paper* **316,** 22 pp.(1923); cf. *C. A.*, **17,** 621.—Two boiler, eight mill, and six drier tests were made at a pulverized-coal plant. A good quality southern Illinois bituminous coal was used which was shipped as screenings and contained little slack on delivery. Complete data on the Lopulco furnace, two 3 pass Stirling boilers, superheater, crusher, drier, mills, separator, conveyor, and methods of conducting the tests are given, accompanied by explanatory drawings. The results of the tests are summarized in 8 tables, 4 sets of temp. curves of the furnace gases with the boilers operating at from 102 to 202% of rating, 3 graphic logs of parts of the boiler tests, and a curve showing that the temp. of the flue gas increased from about 495°F with boilers at 100% rating to 640°F at 212% rating. The authors conclude that the results compare favorably with stoker performances under similar conditions. Overall-thermal efficiencies of from 72.6 to 78.2% and boiler efficiencies of from 74.4 to 78.8% were obtained at boiler ratings of 202 and 155%, resp., with CO_2 at 12.9 and 13.6%. The m. p. of the ash (from the Illinois coal used) was so low that when an attempt was made to run the plant on low excess air with high CO_2 in the flue gases the furnace temp. became so high the ash at the bottom of the furnace melted. It could not be removed while the furnace was in operation. The molten ash also caused excessive erosion of the furnace walls. A comparison is made with tests on 4 pass Stirling boilers set in hollow furnace walls. In these tests the temp. of the flue gases was 130°F lower with resulting heat losses of 7 to 10% instead of 12 to 15% as in the present tests. Radiation losses were also $1^1/_2$% lower (see *Ceram. Abs.*, **2** [5], 116 (1923)). W. W. H. (*C. A.*)

PATENT

Storage structure. ALLAN HARVEY WOODWARD. U. S. 1,527,288, Feb. 24, 1925. A storage bin structure comprising a tunnel, a track in the tunnel for a collecting car, a cover over the tunnel having gate controlled chutes along each side, a bin formed above the cover and having continuous stock supporting banks sloping upwardly with a uniform pitch from the tunnel on each side, said walls being formed in part below ground level by the ground walls of the tunnel cut that slope to the tunnel and in part above ground by embankments formed by the spoil from the tunnel, and a concrete facing for said banks which slopes continuously and uniformly at such an angle as to feed by gravity all mat. resting thereon to said chutes.



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EDITORIALS

A MILLION DOLLARS FOR RESEARCH

Not a bad idea. It is excellent. Before there is a possibility of its realization there must be an accurate survey of its need and a definite plan for its use. To have the interest earnings from a million endowment to spend in research without a definite plan for control and direction of its expenditure would result either in confusion or scientific aristocracy.

The ceramic industries need a research bureau or institute to collect and make application of information; to advise with the manufacturers and with the research laboratories regarding scientific fundamentals and their application to industrial ceramic problems; to compile bibliographies; to write books and, in general, to collect, correlate, evaluate and codify the vast fund of information now available. Large sums of money are being and will continue always to be spent in learning anew the facts which are already known. Most of this duplication is necessary as well as inevitable. Check observations are necessary especially under varied conditions and from various points of view. Duplication in research is not by any means useless, but it is folly to repeat investigations in which essential, fundamental and basic data are wanting or when a complete understanding is not had of the factors involved. We need a "loss and gain" analysis of the existing information if technical ceramics is to pro-

gress during the next thirty years in any such degree as it did during the last thirty.

Research facilities we have in plenty. So far as space and equipment are concerned more research men could be employed in the laboratories already available. There is no need for more laboratories. Then too, there are several universities with facilities which are not now, but which would be engaged on ceramic research if properly advised and assisted.

What is needed most is a survey to determine what investigations are most essential and to influence the laboratories to devote their attention to these essentials. If the writer had the annual earnings of a million dollar endowment to spend where it would be most beneficial to the industries they would be spent in an advisory research survey of the literature, the industrial needs and the available laboratory facilities.

With the inspiration, information and thoroughly informed advisory service which would thus be made available it would indeed be very unnatural and unusual if the ceramic manufacturers, singly and collectively, through their respective trade associations would not be employing to a much larger extent and much more profitably the research laboratories now available to them. And if this research advisory agency was functioned properly through and by the trade associations and the AMERICAN CERAMIC SOCIETY, it would represent a unit force that would develop a more liberal federal and state support of our present research and educational institutions.

Then too, there is a distinct need of more thoroughly collegiate trained scientists and technologists. We will not have an adequate number of more thoroughly trained men until more of our college graduates take more work in the colleges. This additional work is advanced work for a higher collegiate degree. Most students, however, cannot with their own resources afford the time and expense involved. Ten or twenty fellowships, at $1000.00 a year apiece, under strictly enforced conditions of qualifications and research problems would make possible the advanced training which is today so much needed.

The million dollar Ceramic Research Endowment is a good idea. It should be encouraged.

THE CERAMIC DIVISIONS IN THE FEDERAL BUREAUS

Are they equal to what they used to be? Are they meeting the present requirements as successfully as they did those of former years? A comparison cannot be made in justice to either the present or the past personnel but a review of the changes in character of research problems may be beneficial.

The bureau men of the former years placed into ceramic literature

exact information. They did the things most needed and helpful in their day. They could not have employed their facilities and time to a better advantage. And it is certain that if the same personnel had continued in bureau service they would be doing the same sort of work as the bureaus are today doing and in just about the same degree of effectiveness for they were men who grew in scientific skill and vision.

But ceramic science and technology have advanced. Much exact information has been checked and recorded and need not be repeated. We wandered through the wilderness of empiricism for nearly thirty years and are just now entering the promised land of ceramic science. We were guided only by empirical facts and methods during those thirty years of wandering. Each new fact established or new theory proved was a beacon light leading to many serious studies and debates. As soon as a new idea or fact came into view it became the subject of investigation by several. To the leaders during those early years of wilderness wanderings each new finding brought a thrill and a concern that left a vivid impression, so vivid, indeed, that in a casual glimpse backward they stand out individually and with undimmed light. Those were the happy pioneer days and lucky was he who then had the facilities and the time to make investigations.

Favorable to making strong impressions by these pioneers was the fact that the research workers of those years were almost wholly confined to the bureaus, state surveys and universities. Nearly 90% of the Annual Meeting programs of this SOCIETY consisted then of papers by men from these research institutions. This brought the bureau men much more into prominence than is now possible when more than 50% of the meeting programs are provided by industrial employees who have facilities and training for the conducting of research equal to those had by the men in the bureaus.

To compare the case at present with that of the past is like comparing the effect of the occasional light in the small town railroad yard to the massed effect of many lights in the large city yards. In the small yards the individual light receives undivided attention. It is recognized and remembered. But in the yard of the larger centers the individual light has no individuality except to him who needs be directed by it and who therefore seeks it out. The bureau workers during the "wilderness" days were marked leaders. They performed creditably. They will not be forgotten. But he who will seek from the present day maze of equally brilliant individuals those who are conducting the work at the bureaus, will find them meeting new problems by new methods but achieving things in quality, quantity and usefulness equal to the accomplishments of any of their predecessors.

The character of the problems has changed. Once it was empirical

studies of material mixtures to determine roughly the effect of the extreme composition variations. Methods of testing had to be devised. With results of these investigations now a matter of record, the present need is to study the product and the effect of variations in materials and in methods of fabrication on the properties which the product must have if it is to best meet service conditions. In short the major portion of the studies now is on product with some regard to materials and fabrication, whereas in the earlier years it was alone on the compounding and treatment of materials without regard to the product.

Then too, the present workers have more exact data, more accurate methods and apparatus and are more interested in fundamental facts. The present workers have these means and this vision of the needs of fundamental data as a legacy from those who searched in the years now past.

The present bureau men enjoy the collaboration of highly trained technical men from the industrial organizations. This too has been a matter of growth the credit for which lies in the general progress which has been made from the empirical to the scientific, from materials exclusively to products quite largely. The industrial technologist is more interested in product. He studies materials and processes with product of a standard quality as his goal. This has lead to improved physical, microscopic and chemical methods and in turn to product specifications and standardization.

With the more exact knowledge of materials and fuels, and of the economics of their use in fabricating products we have three distinct ceramic specialists—the ceramic artist, the ceramic scientist and the ceramic engineer. The plants need most largely the ceramic engineer and the bureaus the ceramic scientist. The engineer is he who employs the findings of the scientists. The artist is he who conceives the shapes, colors and that artistic creation which makes for the product a market demand. The demand for each of these specialists is not the same in all ceramic industries. Some ceramic lines need all three while others need only the engineer, the scientist or the artist. The bureaus, however, have today more than before a greater need for the scientist to supplement the engineering and art of the factory technologists. This narrowing of the function of the bureau men exclusively toward the rôle of the ceramic scientist is one of the inevitable results of the closer collaboration between the bureaus and factories.

And in collaboration with the producer is the user of the ceramic product. Thus is formed a mystic triangle of the neutral bureau scientist and the producer and consumer technologists. Great strides are thus possible. In place of exploring unknown limits of composition variations, they are now seeking the maximum and minimum of such physical properties of the

product as volume changes, conductivity, strength and di-electric resistance in commercial products and the relations of these properties to service life.

There can in justice be no comparison of the present and the past work of the bureaus. At no time have the bureaus failed to serve the ceramic industries in the manner most needed at the time. The present day bureau personnel is in every way equal to any that have in the past served, albeit their previous training must vary with the service they are to render. The bureau men today, more than in former years, must be more highly trained scientific investigators.

PAPERS AND DISCUSSIONS

WHAT THE INDUSTRIES WANT FROM THE CERAMIC ARTIST[1]

By Frederick H. Rhead

If the question, "What do the industries want from the ceramic artist?" were put to me as a psychological test to be answered in two seconds, I would be inclined to answer to the effect that they wanted the moon, and that they stood very little chance of getting it, even in this age of marvelous accomplishments. But I am quite sure that such an answer would be accepted as being neither conclusive nor comprehensive.

After a little thought, my mental reaction on this subject is one where my mind at once commences to formulate questions such as these:

What industries? What artists? What is the relation of a particular artist to a particular industry? What is the present status of the ceramic artist to the present type of ceramic organization in this country? Artistically speaking, how do our decorated ceramic products compare with the decorated ceramic products of our competitors in other countries? Who is to define what is and what is not artistic in ceramic products? Is it the aim of ceramic manufacturers to produce artistic products? To whom am I addressing these comments? Am I speaking as a manufacturer to ceramic artists, or as a ceramic artist to manufacturers? There are a hundred other questions of equal importance—assuming that this subject is important at all. Do the manufacturers know what they want from the ceramic artist? Do they want to know? Does the ceramic artist want to know what the manufacturer needs? Do either of these groups care, or are they particularly interested in essential requirements any further than those covered by the present law of supply and demand and present manufacturing conditions?

A manufacturer is necessarily bound by the limitations within his own organization. But I sometimes think that he rarely develops the possibilities within these limitations, because he unconsciously but quite deliberately imposes further and much narrower limitations on his organization by dictating or controlling a business policy where the artistic and technical standard of his product must be somehow in line, or in the same field as some group of competitors, or rather he appeals to a price market rather than to a taste market.

This statement may seem obscure and involved until it is realized that a sales appeal is first one of selection or personal taste, and then one of price. If two dinner services are approximately the same price, the customer will buy that which is the most pleasing—I will not say the one that is most artistic.

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[1] Presented before the Ohio Ceramic Industries Association, January, 1925.

In order to test this limitation of possibilities (and I am thinking of this question from a purely commercial angle), visit half a dozen crockery stores as a layman and look for an American dinner service. What will you find? You will find that you have the product of some one hundred domestic concerns to choose from. What will be the essential artistic or ornamental difference between the products of these various concerns? So far as the layman is concerned, there is practically no difference except that the decorations vary in detail. Except for certain technical differences known only to the initiated, a product manufactured by one concern may easily have been manufactured by another. That very elusive but quite tangible and marketable quality called style barely exists in the ceramic industry today.

There has been no serious or sincere effort, artistically speaking, to develop a decorative style that can be instantly identified as being the product of some particular concern. In art pottery Rookwood has developed a style which is almost immediately recognized, and which, by the way, has not been successfully imitated by other art potteries after more than twenty years of effort. The Bachelor Tile Company of California has also developed a decorative style of its own.

The Czechoslovakian potteries are now producing ornamental wares which are beginning to appeal to the younger buying generation, and which if not noted by our domestic art potteries, will make terrific inroads in competition with domestic art pottery.

Some of our foreign friends have been making a close study of American organization methods, not as applied in our ceramic industries, but as applied by the Ford Motor Company and other tremendous organizations. The result will be a trade war that can well be feared by us, unless we use all the resources at our command.

The subject of my paper is not what the manufacturers want from the ceramic artist. The title is: "What the industries want from the ceramic artist" or in other words, what should be the contribution or active interest of the ceramic artist in connection with the development of the industry?

In attempting to answer this question, I am speaking as a manufacturer to manufacturers. First, because I have been concerned with organization, manufacturing, and marketing problems during the past ten years, and secondly, because it is a question that no ceramic artist could answer intelligently, unless he had acquired considerable business experience.

On the other hand, it is a question that no manufacturer can answer intelligently, unless he has made a close study of decorative styles; that is, he must be something of an artist. While my opinion of the business ability of the average American pottery manufacturer would not bear repeating here, I will say that he knows a lot more about art than the average ceramic artist knows about business.

Some of my friends who are manufacturers may exclaim, "But why should the ceramic artist know anything about business! We do not pay him for his business knowledge. We pay him for making decorations that will sell." Now I want to make it quite clear that I am not talking to this type of manufacturer. This is the man who manages or controls a little, six or twelve kiln plant, whose business is running on a shoe-string pocket-book and shoe-string brains, whose business outlook or vision lies no further than his nearest competitor, and whose chief concerns in life are the overdue notes in the local bank.

I have often wondered what would happen if Henry Ford should turn his attention to the manufacture of ceramic wares. I mean I wonder what would happen to the great majority of existing manufacturers. I mention Henry Ford at the risk of creating a smile, but after we have had our joke at the expense of the Ford hundred-piece dinner service, retailing for $2.00 or thereabouts, let us do a little thinking.

We already know that Henry Ford is already in the ceramic game. We know he uses millions of porcelain spark plugs. We know the Ford policy to acquire and control sources of supply, and to develop by-products. We know that in big business it is but a short step from the acquisition of raw material resources to the development of these resources, and to those who have followed Henry Ford's business career without prejudice, it will not be difficult to imagine what he could do in any branch of the ceramic game if he attempted to use his resources and genius for organization in connection with the manufacture of ceramic wares, which brings me to the question what the industries want from the ceramic artist.

They want what the ceramic artist cannot possibly supply unless the various industries are organized in such a way that they can use what he has to offer. I can best explain my point by referring to the founding of the AMERICAN CERAMIC SOCIETY, some twenty-five years ago by a handful of men who simply had to get together and talk shop. We all know what happened, and we know what a tremendous influence this SOCIETY has both in this country and in other countries, who are much older in the ceramic game than we are.

Having been brought up or dragged up in the decorative end of the industry, I have tried to find a handful of decorative men who would be interested enough in their jobs and far-sighted enough from a business point of view to want to get together in the same spirit as that of the men who met in those section Q meetings of twenty-five years ago.

Probably there will be such a group when the manufacturers realize that there is a vital need for such a condition.

It is a curious thing that the mind of the average manufacturer in the clay industries is so constituted that he cannot allow his artist to be the arbiter in regard to his decorative wares. The manufacturer himself is

the judge and jury. There is no research work in shape construction, color harmony, ornamental styles, or decorative process work.

The ceramic artist is not a creator of artistic wares. He is, so far as the white ware industry is concerned, a bench lackey who must respond to the whims of a man who may have a certain amount of taste, and who may possess a fairly accurate knowledge of what will sell. But if he is the controlling factor so far as the creator of new designs is concerned, it is too definite that what are considered as new designs are nothing more than variations of either a foreign product or the product of some domestic competitor.

Because the manufacturer is not a designer, he is not a creator. He is a producer, gaging his product by that of his competitors, who are all doing the same thing. Consequently, there is little difference or distinction between the products of the different plants. A pottery manufacturer goes to a lawyer, a patent attorney, an engineer, an architect, a physician, or any other specialist when he needs to be advised in connection with these professions. But I have yet to learn of an instance where he will consult with his art director or decorative man in regard to design or decorative styles.

I do not wish to give the impression that I am supercritical of the manufacturer, because if my comments are critical at all in connection with present conditions, I feel that the ceramic artist in this country is unprogressive, unbusiness-like, and from an organization point of view, possesses the type of mind of an alley cat. As an instance of this type of mind, I would refer you to the reports of the Art and Design Committee of the United States Potters Association.

Let us consider for a few moments the general field of activity open to the ceramic artist. The largest group industry employing the services of the ceramic artist is undoubtedly the white ware or utilitarian field.

The second largest group is possibly the floor and wall tile, faience, and terra cotta field. The third group includes the various art and so-called or alleged art potteries, or I might say, the small potteries who seriously attempt to produce artistic wares, and the larger potteries who produce commercial ornamental wares. The fourth group consists of those factories who utilize, or ought to utilize, the services of expert draftsmen in connection with the construction of the various shapes. I refer to the electrical porcelain, chemical ware, sanitary ware, stoneware, and any ceramic product where shape construction is an important factor.

Having broadly outlined the field of activity, it now remains to define the true profession of the ceramic artist. What is a ceramic artist? Is the gentleman who buys decalcomania, and who arranges these around the borders of dinner plates a ceramic artist? Is the gentleman who paints little sprays of roses and forget-me-nots on the sides of cuspidors

and other useful articles a ceramic artist? Are the gentlemen ceramic artists who have mastered certain practical and decorative tricks of the trade, and who do the same thing no better or no worse year after year? What about the modeler, the specialist who is responsible for the ornamental shapes? Is the engraver, a highly skilled specialist, responsible for some of the finely engraved designs, a ceramic artist? Where must we classify the man who makes the original designs for decalcomania? Are the decorators employed in quantity production ceramic artists? Are mold-makers, who specialize in decorated and ornamental wares ceramic artists? How about the practical potter engaged in ornamental wares? And the technical man interested in problems of color and texture? And the kiln fireman, who must have a thorough knowledge of oxidizing and reducing atmospheres if he is to produce acceptable colors and textures? Is the salesman selling ornamental and decorated wares a ceramic artist?

I would like to say that a ceramic artist is an individual who is directly or indirectly concerned in the development and production of ornamental and decorated clay products, but I question if this definition would be acceptable to the average manufacturer, ceramic decorator, or clay worker. I will say, however, that this definition is not only acceptable to me, but it is one that I apply in connection with my organization work.

Having outlined the field of activity and arrived at a more or less comprehensive definition of the profession of ceramic artists, we must now give some consideration in regard to comparative conditions involved in the production of decorative wares in this and other countries, and check these with the conditions involved in connection with the technical development in this country during the past twenty years. I can make my position clearer by first briefly outlining the technical development in this country. It is an acknowledged fact that the American ceramic manufacturer has realized the importance of the establishment of technical schools. We have these schools at various strategic points. These schools are growing in importance. They are at least the equal of similar schools in foreign countries, and they have fully demonstrated their value in connection with the growth of the industry. We have a CERAMIC SOCIETY which adequately and comprehensively covers practically every phase of the industry, and this SOCIETY publishes a *Journal* which is not equalled by any other ceramic journal in any other country.

The results of these activities are obvious. Technical development has expanded with the growth of these activities. From a technical point of view, we at least occupy an equal position to any other country, and from an organization point of view the American manufacturer can obtain what technical assistance he needs without going abroad for this type of skilled labor. I wish to emphasize the importance of this condition.

We have fine technical schools, a great technical society, the most valu-

able technical journal published, and as a consequence conditions are favorable for the training and development of efficient technical men.

Now none of these conditions exist in connection with the decorative side of ceramics. We have no schools for the ceramic artist and practical potter, and to date, the Art Division of the AMERICAN CERAMIC SOCIETY has not developed to that point where it can be considered as an important influence in connection with artistic development. There is no journal or publication in existence that caters to the ceramic decorative specialist. Consequently, with no provision for the training and development of the ceramic artist, it is natural and obvious that this type of skilled labor is practically non-existent.

If we consider the facilities and opportunities for the training and development of a ceramic artist in foreign countries, we will find that as much attention is given to the training of the artistic specialist as is given to the education and training of the technical man. Practically every town in England and on the Continent that possesses a pottery of any size is practically certain to have a well-equipped art and manual training school offering courses of instruction for the decorative specialist.

The various art magazines are interested in the decorative side of ceramics, and there is considerable literature catering to this particular field. As a result, our foreign competitors can obtain the services of highly skilled decorators as easily as they can obtain the services of technical men. The result is obvious. The concern with a well-balanced organization is more efficient than an organization with one or more essential specialists.

Dr. Mellor, the well-known English technical man, forcibly emphasized this condition during a recent address to his students, all technical men. He is quoted as stating: "About all the students present can take a hen's egg and analyze the shell and contents. Not a student present can lay an egg." Applying this reminder to the field of ceramics, it is not difficult even for an Englishman to see the point.

We have the men who can analyze and work out the various technical problems, but we do not have the men who lay the eggs, or in other words, we do not have the men who are trained and equipped to create, design, and produce artistic wares of a quality that will compare with American products in the furniture, textile, and metal industries.

There are, of course, notable exceptions, but I am taking the ceramic industry as a whole and considering the matter from an organization point of view.

In finally considering the question of what the industries want from the ceramic artist, a comprehensive reply then must meet this question squarely, and must take into consideration the various points mentioned. No plant or group of men can become an important factor in any industrial development unless conditions are favorable for such a development.

The ceramic art specialist is doing what he can under most unfavorable conditions, but he cannot accomplish much either as an individual or group, unless he enjoys the confidence and support of the manufacturer.

The present possibilities of the ceramic industry are such that those responsible for the growth of this industry must give serious attention to artistic and manual training in the ceramic fields. We must have ceramic art schools in such localities as East Liverpool, Trenton, Zanesville, and other industrial centers, and by this I do not mean schools where students dabble in elementary problems of surface decoration, but schools where the fundamentals of shape construction, design and decoration, modeling, mold-making, and the other practical problems involved in practical potting.

These courses of instruction will vary according to the locality of the school. Whether these schools will be under government or state direction and supervision, as is the case with most European schools, or whether they will be endowed by industrial associations, is a matter of no importance so far as the fundamental need is concerned. It is enough to say that when the various ceramic manufacturers as a group realize the vital necessity for artistic and practical training, these schools will begin to come into existence.

To conclude and to finally answer the question of the title of this paper, "What the Industries Want from the Ceramic Artist," is that which the manufacturers themselves must be largely instrumental in supplying, and before this can be done, the manufacturers must recognize the possibilities for artistic and decorative work when educational and industrial conditions are so organized as to make the creation of such work possible.

With due recognition that this is entirely an organization problem, the manufacturers will later come to recognize the tremendous commercial possibilities for artistic products that will be in harmony with the various phases of industrial and social activity in this country.

In closing, I would like to suggest that when the ceramic industries are brought to the same state of organization as exists in the Ford Motor Company, United States Steel Corporation, and other vast industrial concerns, that it will largely be because the manufacturer has come to accept the ceramic artist as a most vital essential in connection with production and marketing problems.

American Encaustic Tiling Co.
Zanesville, Ohio

BIBLIOGRAPHY AND ABSTRACTS ON THE UTILIZATION OF PEBBLY CLAYS FOR HEAVY CLAY PRODUCTS MANUFACTURE

By Fred T. Heath

General

Methods of handling brick clays containing stones. Jos. Keele. *Clay Worker*, **74,** p. 230.—If a clay contains only a few scattered pebbles or rock other than limestone or dolomite, then it may be worked, if its other properties are good. The non-calcareous pebbles can be crushed. For limestone pebbles, conical rolls are the simplest equipment. These remove the large stones and crush the smaller pebbles. With a Diesener clay cleaner, pebbles can be removed from plastic clay. Raising the mullers of a dry pan an inch or so above the surface of the pan allows the clay to be forced through the perforations of the screen plate while the pebbles stay behind and are periodically thrown out. Grinding the pebbles fine in a dry pan is effective but involves the provision of a storage room for drying clay or for use of a rotary drier. Limestone particles must be ground to pass a 30-mesh screen, otherwise the brick will be disfigured. Grinding processes are not usually effective because these methods of grinding do not reduce the particles this fine. A wet washing process is the only effective process, but expensive for common clays. One plant in the United States is using such a process. In certain parts of England the lime particles are ground as fine as possible and then the fired brick are loaded on cars and drawn through a pool of water. This treatment slakes the lime particles quickly and appears to do less damage than if they were allowed to slake and expand slowly from the moisture absorbed from the atmosphere. The Don Valley Brick Works in Toronto fire in continuous kilns with a strong reducing atmosphere and they have little trouble with their lime particles popping. Finally we have to consider the addition of some substance to the clay which would prevent the slaking of the lime after firing. The writer has made many experiments to this end but found that the only practical thing to do was to add some salt to the water used in tempering. A set of test pieces of fired clay containing limestone particles to which 1% of salt was added, have now been standing in the laboratory for about a year and show little or no indication of disintegration, while similar test pieces made up without the salt have gone to pieces long ago.

Stony brick clays. J. Keele. *Brick and Clay Rec.*, **56,** p. 527.—Enlargement of the article previously abstracted. Palissy, the famous French potter, experimenting with various clays in the sixteenth century and recording his impressions of them, says: "There are some kinds of clay which are of evil nature; because among them there are little stones, which, when the vessels are baked, the little stones which are in the said vessels are reduced to limes, and suddenly when they come to feel the humidity of the air, they swell and cause the said vessel to split in the place where they are enclosed, and this is because the said stones were calcined in the baking; and by this means many vessels are lost, however great the labor one may have employed upon them." This quotation expressed the experience of all clayworkers from Palissy's time to the present day. The one plant in the United States which successfully cleans glacial clay from limestone pebbles by a washing process is situated at Hutchinson, McLeod County, in Minnesota. Its operation is described in the report by Frank Grout[1] as follows: "The washing machinery occupies a space not over 20 feet square and 15 feet high and washed 130 yards of clay in a day. The clay from the bank is hauled by cable car to the washer, where it is mixed with an excess of water and agitated by a series of vertical

[1] "Clays of Minnesota," U. S. Geol. Surv., *Bull.* 678.

rods fastened to a rotating cross-beam. The harrow-like motion of these rods tends to throw the larger pebbles toward the center and leaves the fine clay and sand suspended and distributed throughout the washer pit. A bucket elevator of continuous operation dips into the pit near the center and removes the gravel. The gravel, if cleansed, forms a by-product of considerable value. At the sides of the pit a screen of proper mesh allows the escape of the fine sand and clay to one of a series of open ponds in which they are allowed to settle. After a time some of the water is pumped off and the rest is left to sink into the ground. The sand naturally settles close to the intake of the pond and the clay is carried to the farther side. After partial drying, the material is taken to the stiff-mud machine where the clay and sand are mixed in approximately the same proportions in which they existed in the drift before washing. Experiments are now in progress to determine whether the clay is improved by standing in the settling ponds all winter. The gravel is sold for concrete. Both the clay and the sand contain a considerable amount of calcium carbonate, but if care is taken to remove the coarser sand, the lime does no harm and it is certainly less abundant than in the unwashed drift. The plant at Hutchinson is equipped with three round down-draft kilns and plans are made to double the capacity. It has been found possible with this clay, to produce a very good drain tile and hollow building block so that the production of common brick has become secondary." A face brick plant near Hamilton, Ont. fires their limey clay so intensely in round down-draft kilns that there is no bad effect from the lime grains. WM. BURGESS discusses this paper and recommends fine grinding.

Comment of W. D. Richardson on pebbly clays. *Clayworker*, **78,** p. 336.—Comment on paper read by GEORGE M. KRICK before the Indianapolis convention of the N. B. M. A. He relates his own experience with pebbles at a Minnesota plant prior to 1886. This was before rotary driers came into use and our clay was dried in the sun and wind and then stored in sheds. Our aim was not to grind up the pebbles, but to remove them and that is what I would do today under similar conditions. Mr. PRATT of Anoka, machinist, invented the "chain pulverizer." It is an efficient machine which does not grind the clay but whips it to pieces with the chain beaters, leaving the stone whole and as free from clay as though cleaned with a wire brush. These chains were riveted to two vertical shafts, geared together and running in opposite directions, spaced so that when the chains straightened out by centrifugal force, those of one shaft would just clear those on the other. The clay was fed into the center on top and in falling through the machine, was whipped by these chains. The outside casing was of flat bar steel, set in grooves cast in top and bottom plates, forming a flexible shell on which the clay would not build. Around this we placed a canvas cover to prevent the dust from flying. From this machine the clay was chuted into a rotary screen from which the clean pebbles tailed out of the building to the ground below. The machine was efficient but the wear on the links of the chain, as then constructed, caused frequent repairs. Improvement could now be made on such a machine. It required small power to operate and by using another set of pulverizers and screens for a second treatment of the screened material, the smallest pebbles could be removed.

There are three factors to be considered in grinding limestone in clay: (1) The percentage of limestone in the clay. (2) The fineness of the grinding. (3) The temperature at which the ware is fired and the duration of the high fire. E. CRAMER of the Tonindustries Laboratory, Berlin, made some experiments along this line from which he deduced an opinion that it was not necessary to grind the stone finer than one-twentieth of an inch in diameter. Later, MR. DE SHARENGRAD made a more systematic study of the lime-pebbly clays of central Europe. He washed out the stones and then ground and then sieved them into particles $^1/_{50}$, $^1/_{25}$, $^1/_{12}$ and $^1/_{18}$ of an inch in diameter. Some of each size were then mixed with the clean clay in the proportion of 2,

5 and 10%, respectively, and brick made from these different mixtures and fired. After the fired brick had stood in his office a month, those containing 2 and 5% of stone ground to 1/60 of an inch diameter still remained good, though the brick containing 10% of stone of this fineness had begun to split in two weeks. Brick of all the other grades of fineness, containing more than 2% of stone, were damaged more or less. As DE SHARENGRAD found it impractical to grind the stone as fine as 1/60 of an inch diameter, he then tried the effect of longer duration of the high fire. He had been stopping the firing as soon as the kiln had reached a definite temperature, but a microscopic examination showed that the stone remained free and uncombined with the clay. It was therefore sought to bring about a chemical combination by holding the high heat for a longer time. After numerous trials, DE SHARENGRAD fired his clay, holding the high heat for 48 hours instead of 8 hours, with the result that the extra time the goods were exposed to the heat enabled a combination to take place between the lime and the clay and that brick fired under these conditions not only remains free from popping or pitting, but is actually stronger, the slight vitrification that has taken place binding the particles more closely together. DE SHARENGRAD also found that the brick that were dipped in water immediately after being taken from the kiln, "remained sound, even when the largest particles of lime were present."

Treatment of clay containing pebbles. ELLIS LOVEJOY. From page 21 of his book "Economies in Brickyard Construction and Operation."—"Clays containing pebbles should be worked in a dry condition by putting them through a whipping machine to loosen the pebbles from the clay, followed by screening to remove the pebbles. If the material as it comes from the pit is wet, a rotary drier should be used for drying and then the pebbles whipped loose and screened out. On one yard, the pebbles were removed in the dry pan. The mullers were raised an inch or two from the grinding plates. The clay required no crushing except to loosen the pebbles, which could be done in this way. The pebbles remained in the pan while the clay passed through the screen plates. At frequent intervals the pan was stopped and the pebbles shoveled out. Fortunately, the brick machine was of small capacity. Where the pebbles are of some size, they can be removed by grooved rolls, but any small pebbles will pass the rolls and appear in the brick, oftentimes with bad results. Where the clay contains pebbles, especially of limestone, and they are not or cannot be removed, the grinding should be very fine in order to reduce the size of the lime pebbles small enough so that they will not cause 'popping' in the fired brick."

Limestone pebbles in surface clay. QUES. AND ANS. *Brick and Clay Rec.*, **47**, p. 514. OHIO.—We are desirous of being informed as to the most practical method of separating small limestone pebbles from a plastic surface clay.

ANS.—We know of no practical method of securing the elimination of small lime pebbles. The larger stones and boulders can be taken out by using conical roll crushers and disintegrators, by which the stones are gradually worked out of the machines without passing between the rolls. The small lime pebbles problem is best solved by crushing and grinding them so fine that the particles cannot exert a sufficient expansive force to "pop" and so scar the ware after firing.

Brick and Clay Rec., **47**, p. 601.—Additional information on the subject of the above question is volunteered from a reader. When the limestone pebbles are soft and small and are what are commonly called concretions, such as those that form in the loess clays and are called "loess puppchen," little dolls in the clay, such pebbles may be safely crushed fine, down to 1/20 of an inch or better, to 1/30 of an inch in diameter, and left in the clay. This is especially true when the clay fires to a close, dense body and no water can be absorbed to cause slaking, also when the finished brick possesses great strength to resist expansion. This method is also applicable when the lime is of a

porous nature, having little expansion power, but tending rather to close up its own porosity when the molecules expand on uniting with water. It will readily be seen that this problem becomes an engineering study, the idea being to reach a balanced condition in the clay, the force of the lime in hydrating being so minimized as to cause no harm.

With other types of lime pebbles and clays, such treatment will not be sufficient to accomplish the desired result. Glacial clays containing small pebbles or broken bits of hard limestone, must be so handled as to remove the pebbles. Large pebbles can be removed by conical roll crushers, as is done with the Chicago clays, this treatment also being applicable to moist clays as they come from the bank to the machine. Clays containing many small pebbles, ranging down to buckshot and even duckshot size, should be gathered dry and given a complete processing in dry pans with suspended mullers, then elevated to piano-wire screens where they are screened to $^1/_{16}$ of an inch, giving a clay meal about like the meal used in coarse corn bread. The tailings should be returned to the dry pan and the pan cleaned every 15 to 30 minutes as experience proves is most desirable. The best test to determine whether the clay is being successfully treated is to place a finished brick on a steam radiator or in any other dry, warm place and to watch it for a breaking down of texture or "popping" due to slaking of the lime. Striking two bricks together to determine the quality of the ring, if there is any at all, is an excellent test of whether or not the brick retains its structural integrity. The dulling of sound when two such bricks are struck together as compared with the clear ring of two other bricks which have lain out-of-doors for some time, is a good indication of pebble slaking.

Eliminating small gravel in clay. QUES. AND ANS. *Brick and Clay Rec.*, **48,** p. 347. WEST VIRGINIA.—We are bothered to know what is the best method to follow in getting rid of the small gravel in our clay.

ANS.—Small gravel is of common occurrence in many clays and its elimination is always difficult. One method would be to put the clay through a rotary drier and then crush the material in the dry-pan or a swing hammer crusher and then run it over a fine screen. This would make the gravel so fine that the small particles would not bother the fired material. By the use of a strongly reducing atmosphere in the kiln during the latter stages of the firing, the fine particles of lime are rendered still less dangerous. Another method which is successfully used by an Ohio plant is to wash the clay in such a way that the clay particles are floated out. The gravel is thus separated in a very clean state and is shipped in carloads to a gravel company. The water that is used in the washing process and which contains considerable fine clay, is used for pugging the material. After washing, the clay is dried in a rotary drier and is practically ready for the pug mill. The equipment necessary for this operation is rather elaborate, but this particular company is turning out material that will compete in price with any manufacturer in the state of Ohio. Furthermore, the plant is making a good profit and is manufacturing both brick and hollow tile.

If the clay is one that can be put through a heavy smooth roll crusher (one that can be set very close together), it may be possible to crush the gravel fine enough in this way to bring about the same effect that would be secured by drying and putting through a pan. This at least, would be a great improvement over the disintegrator, the latter being a machine that aids in no way in overcoming the difficulty. The smooth roll crusher would also be a cheap method.

Pebbles break cutting wires. QUES. AND ANS. *Brick and Clay Rec.*, **48,** p. 547. NEBRASKA.—I would like to get your advice on grinding clay. Some of our clay contains small pebbles or gravel and one layer contains soft lime concretions. The latter fire white and do not slake in the fired brick but will crack some of the brick in drying, and

being rough, will break the wires on our cutter. The gravel breaks the wires also when it comes opposite the opening between the platens on the cutter. We use a disintegrator for breaking up the clay but we cannot get it close enough together to break up the pebbles sufficiently small to save the wires. Our clay is wet enough most of the time to pug without adding water at the pug mill, so we do not think that we can use a dry pan. Would a wet pan do the work in breaking up the pebbles and concretions fine enough so that they will not break our wires, or would a smooth roll disintegrator do it? We make side-cut stiff-mud brick.

ANS.—As your clay comes from the bank in a very wet condition, it will be impossible to get any efficiency out of a dry-pan, while a wet-pan is a mixing machine and not a grinding machine. It would seem advisable to put this material first through a disintegrator and then through a smooth roll crusher with the rolls set close together. If possible, the disintegrator should be set directly upon the rolls or a combination disintegrator and smooth roll crusher should be installed. This should eliminate the trouble, at least it will better conditions very materially.

Niggerheads troublesome in crushing. QUES. AND ANS. *Brick and Clay Rec.*, **51,** p. 48. ILLINOIS.—We are up against a hard proposition in crushing our shale. Besides other difficulties, this shale contains niggerheads of sizes varying from very small up to four or five inches in diameter. On account of these niggerheads, we were unable to install a roll crusher.

ANS.—With regard to the niggerheads, these will have to be picked out by hand in most any case except in the event that the clay containing them is soft enough to be crushed while the niggerheads are being thrown out at the same operation. This method is being followed at some of Chicago's brickyards where large nodules of limestone occur interstratified with the clay. The method followed in this case is to put the material through conical rolls where the angle of "bite" is such that the clay is "swallowed" while the nodules are thrown off. This process, of course, can be used only in cases where the clay and the niggerheads differ in hardness so that the difference in their angle of "bite" can be made use of.

Lime in the overburden. QUES. AND ANS. *Brick and Clay Rec.*, **53,** p. 568. ALABAMA.—We are having trouble with severe "white-wash" in our brick which probably occurs through unremoved overburden impregnated with lime.

ANS.—Locate the limey clay with hydrochloric acid. It may be possible to pick out and discard the clay that is impregnated with lime but if this is not practicable, then we suggest fine grinding and the addition of the barytes. Fine grinding breaks up and distributes the finely ground lime particles all through the mass of the ground clay. This procedure eliminates, to a high degree, "popping" of the lime pebbles in the finished fired ware. This pitting is due to the lime oxide which hydrates and oxidizes and reverts back again, after firing, to the carbonate. This process is accompanied by a swelling of sufficient force to break away the surface skin of the ware leaving the unsightly white spots to show on the ware. Bear in mind that fine grinding does not eliminate "white wash" but it does prepare the lime for neutralization by adding the barium carbonate. Scumming is also produced by using coal that has a high sulphur content on a clay such as you have.

Stones in clay cause grinding trouble. QUES. AND ANS. *Brick and Clay Rec.*, **53,** p. 982. QUEBEC.—We have always had a little trouble with stones in our clay but up to this time a pair of rolls could grind it well enough. This summer we began mining a new field and we met with such a lot of big hard stones that we were finally forced to stop. Our rolls could not pulverize our clay sufficiently and we wanted to find a machine that would pulverize the clay for an output of 100,000 bricks a day and in a condition that would enable us to make wire-cut brick. What would wet pans do?

The pair of rolls we have been using are 13 and 19 inches in diameter, the smaller one being armed with six knives. From these, the clay goes through a pug-mill in the press. The stones are generally lime and boulders, from pebbles to three-inch pieces. The deposit is not regular, but we have to meet with quantities of these stones here and there. If we could not pulverize the stones it would mean a move of $2000 and the loss of ten acres of good clay.

It is impossible to throw out all these stones in the mining without considerably increasing the cost. On the other hand, we must add a little sand to our clay; the addition of the ground rock could but add to the quality of our brick. We have received the offer of a pair of rolls 30 inches in diameter but smooth. What would our rolls first, and the big ones under, do?

ANS.—We are of the opinion that since you have limestone to contend with in your clay, it would be best for you to get a fair representative sample of the clay as it will run with this rock in it. This should be ground in some way, by hand if necessary, and made into some sample brick. These should be fired in the regular way in order to determine the effect of the lime on the brick. It may be that this test has been made, but you should find what this limestone is going to do to your brick before putting in machinery to crush it. It is obvious, of course, that adding ground limestone to your clay is a different proposition from that of adding sand. If the limestone does not ruin your clay, you should have a comparatively easy time in grinding.

With rocks of the size that you have in your clay, a dry pan should have no trouble in grinding it with no preliminary crushing. We are inclined to believe that a secondary pair of smooth rolls, taking the material after it passes through the first pair of rolls, would do the work of grinding satisfactorily up to their limit of capacity.

Lime in a calcareous clay. QUES. AND ANS. *Brick and Clay Rec.*, **54,** p. 806. NEW YORK.—Will you kindly advise me whether a clay which contains 13.43% of lime and 5.35% of iron oxide should fire red or yellow? The clay in fact fires red. How much lime should a clay contain to be classified as a calcareous clay?

ANS.—We would expect a clay containing 5.35% iron oxide and 13.43% lime, to fire to a buff or yellow color. However, it is hard to ascertain from an analysis what color a brick will fire because the physical state in which these ingredients exist in the clay mass influences to a great extent, the color to which the brick will fire. Some people claim that a good building brick can be made from a clay containing as much as 20 to 25% of lime carbonate, provided it is in a finely divided condition, and if vitrified ware is not attempted. If, however, a quantity of lime is contained in the clay in the form of pebbles, then much damage may result from bursting of the brick when the lumps of burned lime slake by absorbing moisture from the air. Clays containing a high percentage of lime carbonate are used in making common brick in Michigan, Wisconsin and Illinois.

The effect of lime in clay is as follows: It is probably most effective in the form of carbonate, and if finely divided is an active flux. When clays containing it are fired, they not only lose their chemically combined water, but also their carbon dioxide, but while the water of hydration passes off between 840°F and 1112°F the carbon dioxide does not seem to go off until between 1112 and 1562°F. In fact, it probably passes off at a higher temperature than this.

The result of driving off this gas, in addition to the chemically combined water, is to leave calcareous clays more porous than other clays up to the beginning of fusion. If the firing is carried only far enough to drive off the CO_2 gas, the result will be that the quicklime thus formed will absorb the moisture from the air and slake. No injury may result from this if the lime is in a finely divided condition and uniformly distributed throughout the mass, but, if on the contrary, it is present in the form of lumps, slaking and accompanying swelling of these lumps may cause the brick to split.

If, however, the temperature is raised higher than is required simply to drive off the carbon dioxide, and if some of the mineral particles soften, chemical reaction begins between the lime, iron, and some of the silica and alumina of the clay, the result being the formation within the clay of a new silicate of very complex composition. The effects of this combination are several:

In the first place, the lime tends to destroy the red coloring of the iron and imparts instead a buff color to the fired clay. This bleaching action, if we may call it such, is most marked when the percentage of lime is three times that of iron. Another effect of lime, if present in sufficient quantity, is to cause the clay to soften rapidly, thereby sometimes drawing the points of incipient fusion and viscosity within seventy-five degrees of each other. This rapid softening of calcareous clays is one of the main objections to their use and on this account also, it is not usually safe to attempt the manufacture of vitrified products from them, but the presence of several per cent of magnesia will counteract this. It has also been found possible to increase the interval between the points of incipient fusion and viscosity by the addition of quartz and feldspar.

Bothered with stones in clay. TRADE QUIZZ BOX. *Clayworker*, **79.** QUESTION.—We are much bothered with stones from one-half inch to two inches in diameter in our clay. What machine should we use to crush these stones?

ANS.—Rotary drier, dry-pan and screen. Expensive but practical. Conical rolls remove big stones until rolls wear. A disintegrator will snap out many stones but neither this nor rolls will completely eliminate stones. By CAREY P. ELLIS.

Specific Installations to Handle Pebbly Clays

Working a wet limey clay. GEORGE M. KRICK, Decatur, Ind. *Clayworker*, **77,** p. 243.—Their territory, northeastern part of Indiana, does not possess a clay deposit free from pebbles, and the greatest difficulty encountered in the manufacturing of ware from this clay is the limestone pebbles which all of these clays contain. In order to remove this objection, the only thing was to grind the limestone to a very fine state not to allow any of the pebbles to exist that would cause any eruption on the finished ware.

Methods of doing this were as follows: (1) Remove the moisture. (2) Pulverize and screen the clay.

The moisture is removed by means of a rotary drier. This drier is seven feet in diameter and seventy feet in length and has a capacity of 30 tons per hour.

Objections to rotary drier: (1) Investment. (2) Fuel consumption. (3) Power required. (4) Dust. (5) Extra labor.

Fuel consumption depends on: (*a*) Moisture in clay. (*b*) Condition of clay, fine or coarse. The finer the clay the easier to dry and less fuel and greater capacity. (*c*) Fuel depends on the quality and preparation. Egg coal preferred, as it gives a free passage of air. It is not necessary to have a great heat but the passage of a large volume of heated air to pass through the drier. The fuel also depends greatly upon the personal equation of the fireman.

Cost of fuel to operate this drier varied from 25 to 50% per ton of clay depending upon the conditions.

Dust.—As the clay in the drier is being continually agitated, a large volume of air being drawn through creates at the exhaust fan a large quantity of fine dust, which is taken care of by means of a settling chamber and stack. The settling chamber has a capacity four times that of the exhaust fan so that when the air leaves the fan it travels at a much lower velocity, which is a great aid in settling the dust and prevents it from going out into the open.

Power required to operate this drier under full load is 15 h. p. and 10 h. p. to operate exhaust fan.

Advantages of rotary drier: (1) Uniform moisture in clay. (2) Lessens cost of grinding. (3) Removes all vegetable matter. (4) Makes possible to work clays that otherwise could not be used. (5) Gives better mixture of clays.

The clay from the rotary drier is fed into a ring hammer pulverizer.

Objections to pulverizer: (1) Power. (2) Capacity. (3) Dust. (*a*) Large amount of power in proportion to capacity in tons of clay. (*b*) Great dust agitator-pulverizer must be inclosed and dust removed by an exhaust fan. (*c*) Wearing parts must be removed often. High consumption of lubricating oils.

From the pulverizer the clay is elevated to the screens which is really the most important equipment where limestone plays an important part.

Two gravity screens are used. Top screen is equipped with an 8-mesh wire cloth screen which removes all the coarse clay and gives greater capacity to the bottom screen. The bottom screen is equipped with a slotted wire screen. The wires are double-crimped and rolled so that there is no possibility of wires slipping so as to make an inaccurate sizing. Size of slotted wire screen opening $^1/_{20}$ x $^1/_2$ inch, size of wire 0.072, surface 72 square feet.

In practice it is found true that the greater the per cent of lime the finer it has to be ground. This plant was so equipped to grind as fine as 40-mesh.

The objection of fine grinding: (1) Difficulty to carry and store. (2) Cause great columns of dust. (3) Lessen capacity. (4) Drier and kiln loss. (5) Finished product inferior in quality. (6) Impossible to feed regularly into pug mill by means of disc feeder.

By not working a clay whose contents will exceed 5% in lime pebbles, we have no trouble with lime eruptions to injure the quality or sale of the ware.

Advantages of fine grinding: (*a*) The clay is not so tough and sticky, breaks up well and made easy to work in pug mill, making complete homogeneous mixture which is very essential to making hollow ware. (*b*) Before this process was installed an average of eight tons of ware an hour on a 44 x 20 sewer pipe press has been increased to an average of eleven tons per hour. (*c*) While the capacity has been increased, the operating load remains the same. No improvements or changes of any kind have been made in the power plant, but upon comparing records show that no more fuel was consumed and by indicating the load show no increase in h. p. (*d*) By having this clay in almost a perfect homogeneous material has decreased the drying time 25% and dry room loss from 5 to 10% to less than 1%. (*e*) Average time of firing a 40-foot kiln of 155 tons of ware was 95 hours, has been reduced to 70 hours, making a saving of about 25% in time, and firing loss has been reduced from 20% to less than 10%. (*f*) The color of the ware has been somewhat unpopular owing to the lime, but the ware has a good smooth surface and a clean metallic ring when struck with a hammer and will withstand more severe handling.

Discussion follows: WILLIAM HAMMERSCHMIDT, Lombard, Ill.: We had the same trouble as MR. KRICK. We are located in northern Illinois and had limestone in our clay. We had our troubles and we changed to the dry clay system putting in a Penfield disintegrator. We have a large dry house. We dry our clay about six weeks in advance of the time we are going to use it. We run our clay through the disintegrator, which is fed by a conveyor which runs underneath the storage bins and feeds uniformly. We take up all the lumps in that way. Our screen is about 8 wires to the inch. The tailings return to the Williams pulverizer, whereby we increase the capacity of the machine so much more, that we could use a smaller machine. We take out about 50% of the clay at the first screening and by returning to the pulverizer we have a con-

tinuous run until everything is pulverized to the fineness of corn meal. We have reduced our time of drying and firing and have better ware. We dry our drain tile on the flat.

OTTO TRAUTWEIN, Chicago, Ill: Does MR. KRICK put his clay through the rotary before or after it goes to the storage bin?

MR. KRICK: The clay is brought in and dried before it goes to the storage bin. It is dried and screened and then placed in the storage bin.

W. C. HOOVER, Portland, Ind.: At the Portland Drain Tile Company we got into the lime trouble before MR. KRICK did. Along in 1913 we began to run short of surface clay as we call it, and we could not get any clay near us so we had to shut down. We are making 32-inch tile at the Portland plant out of hard pan and a surface clay above that. For two years we had more trouble than you can imagine, but we finally got the limestone handled successfully. We had a Williams crusher put in and we built a large storage bin which helped. Our bank varies from 12 to 15 feet. As MR. HAMMERSCHMIDT says, we have eliminated our losses in the sheds for drying and somewhat in the time of drying also, but the best thing of all, we improved the quality of our ware very, very much.

W. L. BELTZ, Mowrystown, Ohio: What size mesh does MR. KRICK use? Does it run as high as 40-mesh?

MR. KRICK: It varies in my clays. In some places it runs as high as 30%. We have carefully analyzed the amount of lime, and have places where it runs as high as 25%. We never try to grind that clay. We use as high as 30- to 40-mesh but are troubled with dust.

MR. HAMMERSCHMIDT suggests use of a worm feeder run slowly to feed the pug mill.

Plant of the Delaware Clay Manufacturing Co. F. E. MILLER. *Clayworker*, **63**, p. 643.—General description of the plant. After being hauled inside, the clay is dumped into a hopper and by means of a drag chain conveyor, is fed into a coal-fired drier which is 40 feet long and $5^1/_2$ feet in diameter. This large drum is revolved slowly, and being set on a slight angle, provides a gravity discharge. An exhaust fan draws the heat through in the same direction as the material, and aids in getting the dust through, as angle iron projections on the inside reduce a large proportion of the clay to dust. After passing through the drier, the material is raised by a chain elevator to the screens, these excluding all stones larger than a hen's egg, these passing by a chute to the outside of the building, the finer material being fed into nine-foot dry pans and crushed. From here it is elevated and passed over a series of fine-mesh screens through which nothing but dust will go, this being fed into a storage hopper ready for the eight-foot tempering pans. The dust covered gravel that is excluded is passed through a washer and sold as a by-product, while the clay-laden water is utilized in the tempering pans.

The separation of stones from clays. C. H. SOLFISBERG, Aurora, Ill. *Clayworker*, **58**, p. 512.—Lime is not so important in manufacturing common brick, because a pop in the face can be overlooked. Limestone pebbles from the size of boulders down to fine dust occur in the clays of Wisconsin and Northern Illinois. There is a difference between air slaking and water slaking, the first being a short direct combination, the latter is a longer timed double reaction and lower pressure is exerted. I have given the above theory to show you that a brick can often be saved from popping by soaking in water. This was discovered accidentally due to rain. We must find some method of removing limestone. The entire content can be removed by suspension of clay in water, passing over sieves and settling out in vats, but the excessive cost makes it impractical for the common brick manufacturer. There being a few advantages in a small lime content, such as aid in drying, and help through sudden changes in temperature,

we need not remove all the lime but must have it sufficiently reduced in size. The method I will speak of, is in successful operation at the present time and makes it possible for us to make a strong brick from a clay running a strong 10% limestone. Ten per cent limestone is excessive and appears to be gravel instead of clay. I do not think this method is perfected as yet and each clayworker would have to alter it for his special clay. Pick and shovel methods with aid of dynamite removed larger stones at a fairly low cost. There are cheaper methods of winning but not for this clay. A piece of clay when struck by a hammer will break up without touching stones within it. Hammer mill purely impact, would do the work, reduce the clay and not the stones. A machine was built and installed. I will not detail screen trouble, but we tried all kinds until a piano wire did the work. The hammer mill is constructed with open grate bottom and six-inch grinding plate.

This method has its disadvantages of course. A wet clay separates less rapidly and has to be run through the system until stones only return. If clay is too wet, the mill will plug up. Wet clay is dumped from cars to dry-shed floor and run through later. The average bank moisture is nicely worked. A clay drier would make the system more perfect as stones would return clear of clay. As to the cost of operation, a 50 h. p. motor drives mill, cable drum and conveyor belt, and takes clay as fast as one man can feed it. The hammer, if of cast steel, would last about one day; tool steel, best obtainable, will wear off an inch in ten days of damp clay run. Manganese cast steel hammers have just been installed and are guaranteed to last over twice as long as any tool steel made. In dry clay, the wear on mill is lessened greatly. The case of the mill will last two seasons if one inch thick of cast iron; $1^1/_4$ inch steel bar grating will last about a season. This is for a very stony clay and wear will vary in proportion to stone content.

This method reduces clay to $^1/_8$ inch and less. The estimated cost of preparing clay for the brick machine is thirty cents per yard. If less than $^1/_8$ inch material is desired a crusher can be used since stone content has been reduced to about 1% in a 10% lime clay.

Winning the fight against failure. ANON. *Brick and Clay Rec.*, **49,** p. 410.—Manufacturers of brick and drain tile with their clay part of a gray glacial drift, containing an unusually high percentage of limestone and gravel, both of which had to be removed if a satisfactory product was to be obtained. Practically every method of eliminating the limestone pebbles and gravel has been tried. After the failure of other methods to successfully accomplish the separation of the impurities from the clay, a washing machine, which was designed by the owner of the plant after many years of experimenting, and which is somewhat similar to those in use for the same purpose in Europe, was erected. The parts of the machine were, in fact, imported from Europe. The method has been used five years at this plant. It is an expensive and ordinarily undesirable process.

The washing machine itself is about 15 feet high and 20 feet square, being capable of taking care of 130 yards of material per day. When the clay is thrown into the machine from the car, it is mixed with an excess of water in a cylindrical washing pit at the bottom which is about 4 feet deep. Here the mixture is agitated by means of a series of vertical rods that are suspended from the cross-beams of a rotating wheel arrangement, said beams centering in a revolving shaft in the middle of the pit like spokes into the hub of a wheel. The movement of these rods in the machine throws the larger pebbles toward the center of the washer while the fine clay and sand become suspended in the water and distributed in a fairly even manner throughout the pit. The gravel and large pebbles are removed from the center of the washing pit by means of a bucket elevator that is operated continuously. This elevator, since it is attached

to the center shaft, revolves with the same speed around the pit as the rods that stir up the water. As the buckets are filled, they are elevated to the circular shelf at the top of the machine, where they deposit their contents. Following the course of the buckets is a rod attached to the center revolving shaft that sweeps the discharged material into an inclined trough at the rear of the machine. Since the buckets dip considerably below the surface of the water in the washing pit in removing the pebbles of limestone and gravel, they are bound to elevate some of the suspended clay. In order to reclaim this material, the inclined trough into which the elevated material is conducted is kept overflowing with water, this again suspending the clay particles and carrying them over the edge of the trough back into the pit. After the gravel has been swept into the trough it gradually works to the other end where a second elevator is at work raising it up and over a platform from which it throws it in a pile on the ground. A stream of water is kept running down this platform washing out of the buckets all of the suspended clay that may have found its way to that point, sending it back into the pit.

The gravel is so clean that it may be used for concrete work. Going back to the clay in the washing pit, we find it is suspended there in the water with fine particles of sand and is allowed to escape through a screen of the proper mesh on the front of the machine. The passing of this clay through the screen insures only the very small particles of clay and sand getting through and prevents any of the large pebbles, either gravel or limestone, from finding their way to the settling pond to which the suspended mixture is led from the washing pit by means of a trough.

The clay is allowed to settle in one of the three or four ponds. The sand being heavier, settles nearest the intake, while the finer and lighter clay matter is carried to the other end of the pond. This results in a very uniform gradation from the sand at one end of the pond to almost pure clay (90% kaolin) at the other end. After partial settling, some of the ware may be pumped off and the rest allowed to evaporate and sink into the ground. The clay is then subjected to one year's drying and weathering.

When ready for use, after having been in the field for a year, the clay and sand are again mixed in approximately the same proportions as they originally existed in the pit and sent through the ordinary processes of manufacture. The clay in the ponds from which the pug mill is being fed, is in a comparatively loose and unpacked condition and is too soft to support the clay gatherer or a cart after a rain. It is necessary, therefore, to guard against this emergency if the plant is to be kept operating at capacity throughout the season. This is done by transporting some of the weathered clay from the drying fields to solid ground. Two horses and as many carts are continually in use performing this duty, adding another item to the cost of the manufacturing.

This system represents a tremendous investment and much additional expense above that usually met with in this branch of the industry. However, it opens up for utilization, a vast amount of clay that has heretofore been considered worthless because of its impurities.

Pebbles in clay. QUES. AND ANS. *Brick and Clay Rec.*, **42**, p. 275. CALIFORNIA.—We have a limestone clay full of pebbles and experience considerable trouble with it. Can you suggest some remedy?

ANS.—There are crushers on the market that are said to remedy troubles such as you are experiencing. There also is machinery expressly made for washing clays that is used by brick and tile makers. A hardwood washer which we have seen, satisfied its builder. It is a circular vat about 14 feet in diameter. There is a shaft in the center and on the top of that is a bevel gear and a band wheel. There is a lever near the bottom to which is fastened a chain drag made of two or three 3 x 4 scantlings with long teeth.

One corner of this drag is fastened to this chain and the other to the center shaft. Dump your clay into the vat from the cart, a little at a time. An inch and a half of water should go into the clay continuously. The slush from the vat goes into a screened box say of 4 meshes to the inch for brick and tile. From this box the slush goes to the drying places, of which there should be two. It can run through a common wooden trough and should spread over a considerable territory. Our friend washes the clay in the spring and lets it lay until the next year before he uses it. In this manner it freezes and weathers and is in a good condition to use.

To eliminate lime pebbles. *Brick and Clay Rec.*, **43**, p. 692.—Suggestions of OTTO POMMER of Quebec, Canada, were submitted to an experienced brickmaker, whom he knew had gone through a long series of experiments with the object of eliminating the lime pebbles from his shales. He writes us as follows:

I think that MR. POMMER is correct in his description of the chemical action of lime pebbles, and two of his suggested methods would doubtless be satisfactory, *viz.:* To wash the material when the lime is in large enough pebbles to be removed by washing; or by increasing the temperature of firing the brick, provided the material will stand the higher temperature and that the resulting colors would be satisfactory. The other two methods I do not believe feasible. I have found it impossible to grind pebbles fine enough to prevent their popping. Dipping the brick in water after leaving the kilns would only result in bringing the pebbles out quicker. I would suggest that the most practical way to eliminate trouble with lime pebbles is to keep them out of the material when it is loaded in the pit. In nearly all shales and many clays, the pebbles are found not in the material itself, but in the overburden. Therefore, by careful stripping and using muriatic acid to show effervescence when the pebbles are present, it is possible to practically eliminate them.

MR. POMMER'S article follows: The existence of lime in clays or shale used for brickmaking is a source of constant trouble and it is up to every plant which has the trouble to find out which remedy will work and suit the conditions best. Carbonate of lime is often found in clays. Sometimes it is very fine in which case it does not do harm but acts as a flux, and in other cases it appears in the form of lime pebbles in sizes that vary from that of a nut down to a head of a pin. When firing, the lime loses the carbonic acid, leaving oxide of calcium, known as unslaked lime, which absorbs the water from the air, forming hydrate of lime, known as slaked lime. In this stage the lime increases its volume, forming cracks in the brick which grow bigger until pieces fall off from the brick and cause the brick to burst. Looking at those pieces the slaked lime is easily seen. There are four ways known which might help.

1. To wash the material. This is the safest but most expensive way. To do this, large basins and a large amount of water is necessary. If the clay contains lime in small amounts and fine particles only the firing color of the products will be very much improved and the prices obtained might pay the expenses of such washing.

2. To reduce the size of lime pebbles by crushing. The crushing must be done very fine by means of 2 or 3 smooth crushing rollers, the rollers spaced from $^1/_4$ to $^1/_{16}$ of an inch apart, one roller on top of the other. These rollers must be kept in a very good order so that no bigger sizes of lime pebbles can pass. The pebbles should be crushed fine enough to handle the material.

3. Dipping the brick in water as soon as they are drawn from the kiln. In this way the lime is suddenly soaked and drowned. The pores of the brick are filled with lime-milk and thus closed up with lime, in this way keeping away the air from the inner brick, preventing still unsoaked lime pebbles from being soaked and so harming the brick.

4. The last way would be to overfire the lime pebbles. This means to fire the brick at as high a temperature as the lime will stand, thus burning the lime dead.

To find out which way will prove the best, I suggest the following tests: (1) Wash

enough clay to make 5–10 hand-molded brick over a 30-mesh sieve. All the material going through the sieve used to make the brick; fire those. (2) Crush the lime pebbles of your materials to 4–5 different sizes and add those different sizes to your material which must previously be washed or finely screened so that there are no other lime pebbles in the material as added to the one crushed to different sizes. After those test brick are fired and exposed to the air, it is quickly seen to which fineness you must reduce the lime pebbles so that they do no more harm to the brick. (3) Place about 50 bricks of your regular make for five minutes entirely under water until no more air is coming to the water surface, then expose the brick to the air and after a few days you will see if this helps. To do this with little expense, wheelbarrows with the brick from the kiln are placed on a double elevator, one side of the elevator going down in the water, the other side coming up, so one wheelbarrow is always under water. (4) Try to fire your brick with more heat. There are some limestones which are burned dead by certain temperatures. This way is the easiest. I met the lime trouble at a plant at Detroit, Minn., where the lime pebbles were in the worst form. The plant was making soft mud brick and used field kilns. When starting at this plant I installed one crusher with smooth roller, crushing the pebbles just to minimum size. I also increased the temperature of the firing and got excellent results, the lime troubles having disappeared.

Saves $4000 yearly by device. THE SUPT. *Brick and Clay Rec.*, **43**, p. 693.—The Westport Brick Co., of Baltimore reports an annual saving of $4000 by the installation of a clay cleaner. The labor of three men at $1.75 a day was saved and a granulator, a disintegrator and a rotary drier were eliminated, the clay going direct to the dry pan. A ton of coal per day at a cost of $3.40 per ton is included in the figures and only 15 h. p. is now required where 175 was necessary formerly. The actual saving in labor and coal alone is $3162.50. The Westport clay is plastic and is fired into pavers.

Wet Washing Equipment

Wants clay washing machine. QUES. AND ANS. *Brick and Clay Rec.*, **43**, p. 691.—Information on a machine, a sketch and description of which is given. This shows an inclined cylinder enclosing a rotating spiral with clay and water fed in at the lower end and the coarse material being carried above the water level and falling into a chamber, the fine material all being carried off in suspension in the water. The answer gives no particular information on this type of washer.

A new clay washing device. *Brick and Clay Rec.*, **45**, p. 814.—ERNEST TECHEN, a German, holds a patent on a device which automatically removes and separates from clays and kaolin, impurities like quartz, granular lime, pyrites, etc., and such foreign material as straw or wood.

There have been devices on the market for some time for washing clay, which consist essentially of a screw conveyor operating in a long inclined hollow drum or cylinder. The undesirable material as it settles out of the slip, is carried forward by this conveyor, a separation being thereby affected. These machines were uneconomical in their operation, the output of purified clay being too low for the amount of work represented. A complete purification was not effected, furthermore, and for this reason settling tanks were also employed to bring about further purification.

This washing device differs from the one mentioned, in that the drum or cylinder rotates while the screw is stationary. Full description is given.

A simple sand and gravel washing device. THE SUPT. *Brick and Clay Rec.*, **51**, p. 137. (Sketch).—The device is merely a screw conveyor set into a pipe, the whole device set on a frame at an angle sufficient to permit the water to run freely to the lower end of the water outlet. The water is admitted at the upper end, and the gravel shoveled into a hopper at the lower end.

Plastic Clay Screening

The Diesener clay cleanser. RICHARD G. HOFFMANN, La Grange, Ill. *Clayworker*, **52,** p. 644.—Homogeneous clay is of prime importance in successful manufacture. Clays are better prepared in Europe than in the United States. Weathering is the oldest method employed for homogeneity. This allows a rapid and thorough mixing and tempering by pans, disintegrators, pug mills, or other machines. Clay is further improved by aging.

To prepare clay relatively free from impurities and one that is not tough, the pit or the common pug mill will give satisfaction. The latter is often combined with disintegrators to break up the big lumps of clay. If two or more diverse and very heterogeneous clays have to be mixed in a certain fixed ratio, the wet pan with solid bottom will give best results. A modification of the wet pan is built with a perforated bottom. This style has, under similar conditions, a larger capacity as it can be charged and emptied automatically, but its mixing properties are not as perfect as those of the solid bottom pan. Another style has been designed with several bottoms, located one above the other, but secured within the same frame and driven by the same shaft. The crude clay is fed into the uppermost pan, having numerous slots, and it is driven through these to the second bottom, having finer slots, and finally to the lowest bottom, from which it goes to the next process.

Another machine uses a pair of rollers, each consisting of strong cylindrical ribs supporting a cylindrical surface made of perforated sheet metal. The clay drops between these rollers and is forced through the slots into the rollers themselves. From the inner surface the clay is scraped off and removed into chutes. The rollers are pressed against each other by means of strong springs, which allow the rollers to increase their distance every time a stone drops between them which is too big to pass through the slots into the rollers and is consequently ejected. This machine is said to consume less power than the previous one mentioned, based on the output given. It is not adaptable to tough clays. It is claimed that the cost of maintenance with these machines is very small.

The latest in the design of pans has a solid bottom, upon which two heavy mullers run with attached scrapers so arranged that the clay is discharged automatically as soon as it is ground down to a certain size. The charging of this pan is designed to be automatic. The scraper, which defines the smallness to which pebbles, etc. shall be reduced by the mullers, throws everything back under the mullers which cannot pass between the bottom and this scraper. This can be set at $^1/_{16}$ inch from the bottom, or if more output and less fineness is wanted, the adjustment of this scraper can be changed in a few minutes.

What will the machines mentioned do on a clay that is very tough and contains pyrites? Or on clay that is very sandy and filled with pebbles of limestone? A guarantee that the prepared clay would contain nothing detrimental to making of flawless fired goods could, heretofore, only be given by the screen and only with clays in which just a few per cent of these undesirable ingredients occur, or by the washing process. To use the screen the clay must be piled up, dried, milled or ground and then screened. It is evident that in this case the impurities are still in existence in the clay, although in powdered form.

By far the best method of removing these impurities, if they are not soluble in water, is still the washing process. It is done by combining washing tanks with settling pits or with filter presses. Unfortunately the washing process removes with the impurities, the desirable quartz and feldspar sands.

In the use of the DIESENER method, the clay may be worked as it comes from the bank without weathering and it does not matter if it be dry or wet. The clay is first

put through a pug mill to break it up, mix and water it. From this pug mill, the pugged clay falls into the hopper of an auger machine and comes out in the form of a bar, then passes through the DIESENER machine. If the clay is very tough and impermeable to water, it may be crushed through a roller crusher before being sent through the pug mill. The rolls of the crusher should be set apart about one inch. The pug mill may have 1 shaft and be 16 feet long or have 2 shafts and a pugging trough 6 feet long, the choice resting with the rate of slaking of the clay. The pug should have 50% greater capacity than the cleaner so that the clay soaks longer.

The auger machine issues forth a bar of clay usually about 22 x 4 inches. This should preferably be in stiff mud condition, if the clay is very plastic; or in soft mud condition if sandy. The DIESENER clay cleanser operates as follows: The bar of clay goes down an inclined plane and is pushed against the rotary disc of the cleanser and "sucked" by it through a slot (sketch). The width of the slot is adjustable down to $^1/_{16}$ inch. The stones are removed by a stone pusher or a knife that reaches from underneath into the slot. The knife must be thinner than the slot and if a slot of $^1/_{16}$ inch is used, the knife will not be strong enough to remove a stone larger in diameter than about $^1/_2$ inch or one inch. Pebbles of larger size may be ejected or crushed before the pugging process by a roller crusher with the rolls set at $^1/_2$ or $^3/_4$ inch. This would be done if the total impurities in the clay amount to only a few per cent. If many pebbles were in the clay, this crushing would decrease the output of the cleanser too much. In this case it is more economical to use 2 DIESENER machines in series, the first with a slot of $^1/_4$ inch for removing the coarse stones and the second with a slot of $^1/_{16}$ inch for the smaller impurities. As soon as the clay passes the slot, it drops in shape of shavings or snowflakes or if it is so wet as to stick to the disc, it is thrown off by an attached scraper. Six to twelve h. p. are required for the cleaner and 15 to 25 forth e auger pug mill. From 100 to 250 or more tons per day is the capacity. The knives wear out but can be made from hoop iron, the disc has to be faced one or two times a year.

Further information regarding the Diesener clay cleanser. RICHARD G. HOFFMAN. *Clayworker*, **53**, p. 448.—The power consumption is low because very little friction is developed in the clay itself The action of the rotating disc and the inclined plane upon the clay is illustrated by spreading clay over a plane surface with a knife. This is the method that the old time potters used to clean their clay, the edge of the knife tearing to pieces lumps of tough clay and extracting the stone, according to the thickness the clay is spread upon the table. Wearing on the disc is only caused by the stones which did not follow at the speed with which the clay is sucked through the slot.

It will be unanimously admitted by every practical clayworker who has seen the machine in operation that this clay cleanser has reached a degree of perfection which is unsurpassed by any other mechanical process for the same purpose under similar conditions.

Grinding Apparatus

The grinding and screening of clays. *Brick and Clay Rec.*, **43**, p. 285.—The purpose of grinding is to break up and disseminate impurities and to promote plasticity in the clay itself. Wet grinding is used where defective plasticity is found as it is the best known method for developing latent plasticity; but at the same time the method is inefficient in securing physical homogeneity. In general, dry grinding is practiced where the material is unhomogeneous naturally, and where its lack of homogeneity would cause trouble if not overcome. It is followed ordinarily by screening which establishes the limit of size of the particles and insures uniformity. Thus it is seen that the wet and dry grinding processes are more than alternative routes to the same goal. The wet treatment is slower and more costly. The roll is one of the simplest and oldest forms of grinding machines. They are used as a wet grinding machine for crushing

stony, plastic clays, and for rejecting the rocks or hard portions which are too large to fall within the angle of nip, and also as a dry grinding tool for pulverizing large quantities of nearly uniform size of grains. The most common use of rolls in this way is as a tailings grinder to finish the grinding of small particles which are partly reduced, but not enough so as to pass the screens. Differential rolls are used for grinding fine grained alluvial clay which is so plastic as to be difficult to grind in a strictly dry grinding machine like a dry pan. The small roll, about 9 inches by 2 feet long runs at approximately 500 r. p. m. while the large roll, 18 inches in diameter, makes but 150 r. p. m. When clay is fed into the machine it not only squeezes and crushes it, but also shreds and tears it apart as well. Grinds wet or dry clay.

Glacial clays are very heterogeneous in character, containing boulders, gravel, sand, etc., which have been picked up by glacial action. Their preparation offers a special problem. At one plant treating this kind of clay, a pair of conical crushing rolls, smooth surface, set one inch apart and running at 75 r. p. m. handles about nine tons per hour. In size they are 2 feet long by 12 inches at the large end and 7 inches at the small. These rolls crush the lumps of clay and smaller pebbles; and any stones that are too large for the angle of nip gradually work their way to the large end of the cones where they fall out into a wheelbarrow and are removed. The use of these rolls is chiefly for their qualities as stone separators.

The dry pan is the most commonly used machine because of its adaptability to handle the material if it would come in widely varying sizes or degrees of hardness, degrees of plasticity and in rates of feeding. The step bearing is one of the most essential features about a dry pan and must be well lubricated. Disintegrators of the hammer mill type are used some, but require dry clay and even then provision is made to steam heat the jacket of the mill in order to prevent the clay from packing in it.

After a clay has been through a pan or equivalent, and is in the form of a coarsely granulated powder, the screening still remains difficult if the moisture exceeds 5 or 6%. Caking on the screen, covering the holes, agglomerating and rolling on the surface without passing through, sticking in elevator cups, choking spouts and runways are troubles incident to dry clay screening. As the coarse particles in a ground mixture also are likely to be the hardest and also of different chemical composition from the matrix of fine aluminous material, it follows that these coarse particles are both difficult to grind finer and are the most injurious to the clay if not reground and made to blend well into the matrix. Screening is therefore necessary to establish a limit beyond which particles cannot enter the clay body except by accident. It is a very necessary part of the process of homogenization, of which grinding and tempering are the two principal steps. Piano wire screens are made adjustable by varying the pitch of the guide rods through which the wires are threaded, at both ends. When properly constructed and kept in condition this screen has large capacity, does not bind easily, requires no power and little headroom. A centrifugal screen is in use at a plant in Alfred, N. Y. It consists of a large funnel-shaped receptacle, 4 feet high with a diameter of 9 feet at its upper or large end. The screen is supported on a central shaft with spiders and suitable bearings at top and bottom and revolves with the shaft. Clay is fed into the center of the rapidly revolving cage and upon striking the bottom of the cone, begins to move up the sloping sides of the cone by centrifugal force. The fine clay passes through the perforations, while the coarse material is carried up and over the top, whence it is returned to the rolls for regrinding.

Grinding crusher rolls. THE SUPT. *Brick and Clay Rec.*, **50**, p. 1238.—Conical rolls used to grind the clay and separate from it pebbles and large stones, formerly were sent to the scrap heap when the stones had gouged deep enough into their surfaces to allow stones and pebbles of a troublesome size to pass through. In the place of a dis-

carded roll, whose period of service usually extended about three months, would be mounted a brand new roll. A sketch of a device is shown with which it is possible to easily grind down the surface of the rolls and thus increase their life.

Theory of roll crushers. THE SUPT. *Brick and Clay Rec.*, **51**, p. 499.—The object is to have the rolls of such a diameter and set at such a distance apart so that they will pull the lumps down through the rolls and yet not utilize excess power. If the rolls are too far apart they will not crush the material properly. On the other hand, if they are too close together they may crush the material more than is necessary, thus wasting power, or it may happen that the material will not be drawn through the rolls, but will simply slide between them and tend to stuff up the crusher (sketch). The angle of nip may have values from 0°, where the space between the rolls is as large as the lump fed, increasing upward until the angle is so large that the rolls cannot nip the fragments. The angle of nip in any case will depend for its value upon the diameter of the rolls, the diameter of the lumps fed, and distance apart at which the rolls are set. It is also affected in the following ways: It is diminished by increasing the diameter of the rolls (the space between the rolls being kept constant); by increasing the space between rolls, and by decreasing the size of lumps fed to the rolls. All relations between size of material, space between rolls, radius of rolls, and angle of nip can be expressed by a simple formula, which is derived as follows: If b = the radius of the sphere to be crushed, a = $^1/_2$ of the space between the rolls, N = the angle of nip, and r = the radius of the roll which is equal to $^1/_2$ of the diameter, then $\frac{r+a}{r+b} = \text{cosine}\,\frac{N}{2}$.

To effect a reduction, the friction F (sketch below) between the sphere and rolls must equal Ku, where K is the force of the reaction and u is the coefficient of friction. In terms of a force system as represented in the diagram, the component $F \cos x$ tends to draw the clay between the rolls, while $K \sin x$ tends to push the sphere out and hence acts in opposite direction to the force $F \cos x$. If the above forces were equal, the following equation would hold true: $F \cos x = K \sin x$ or $F = K \tan x$. From this we conclude that for the rock to pass through the rolls, u must be greater than tan x and, hence, the angle x must be less than the angle of friction.

Protecting crushing rolls from large stones. ANON. *Canadian Clayworker*, Aug. 1915, p. 11.—With a pair of smooth rolls for crushing clay which contains pebbles, trouble is sometimes caused by stones which are too large to be crushed becoming pinched against the rolls and causing undue wear on them. Grooves in the rolls are often started in this way which rapidly grow deeper until the rolls have to be ground down or discarded. Conical rolls, owing to their shape, cause all such stones to finally work toward the large end of the roll where they are free to fall out of the machine. But even with this shape of roll trouble is encountered in the prompt removal of stones which seem loath to depart until they have tarried long enough to leave their mark upon the rolls. The accompanying illustrations show a home-made contrivance for overcoming this difficulty which is in operation in a Canadian drain tile plant. A rod carries an iron point on its end which removes the stones from between the rolls. A crank turn to which is attached a connecting rod which actuates the rod with the point from left to right causing the stone picker to drag out

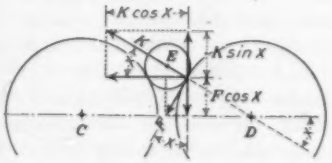

FIG. 1.

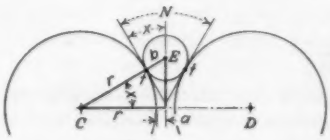

FIG. 2.

any stones which may be between the rolls but too large to be crushed. On the return stroke, the bar with the picker is lifted by means of the cam-shaped crank and is pulled from right to left passing over the stones. At the end of the stroke the picker drops down close to the rolls and the operation is repeated at the rate of about ten strokes per minute.

Improved clay disintegrator. ADV. *Clayworker*, **15,** p. 5.—A cut of a multiple squirrel cage type of disintegrator of which the interior portion revolves in opposite directions to the outside cages. This was marketed by Stedman's Foundry and Machine Works, Aurora, Ind.

Reducing costs in grinding clay. ANON. *Brick and Clay Rec.*, **53,** p. 1152.—Not sufficient consideration has been given to the ring pulverizer which has proved its merits on several plants where such advantages as higher capacity, relatively lower repair costs and less attention required, were found. In the impact type of pulverizer the rings each weigh 27 pounds, while the hammers weigh about 17 pounds apiece. A hammer is placed behind each ring and serves to dig up that which the ring rolls down, thus preventing clogging.

Grizzlies and Screens

The pros and cons of clayworking screens. ANON. *Brick and Clay Rec.*, **53,** p. 295.—Clay working screens require constant attention and often necessitate a boy at hand to keep cleaning them. Different clays require different types of screens for best work. The good and bad points of screens in general are discussed in this article. There are three types of screens used in ordinary clayworking: namely (1) the perforated metal screen, (2) the woven wire screen, and (3) the piano wire screen. The first named type is becoming increasingly popular although the woven wire screen has been used to a very great extent. The proportion of open space to solid metal in the perforated screen as now made approximates that of the wire screen which gives it an equal screening power.

To prevent decreased screening. THE SUPT. *Brick and Clay Rec.*, **55,** p. 1054.—Among the winter difficulties experienced in clay plants is the decreased capacity of the dry pans. In wet weather about one-fourth of the material which is poured upon the screens fails to pass through them and is returned to the dry pans, thus slowing up their capacity. To check this and force all through, 3 swinging baffle doors of sheet metal may be suspended at spaced intervals over the screen to throw and spread the dust down onto it. They should be weighted down with iron so as to prevent their swinging to such a height as to make them ineffective. By using those baffle doors, the dust is thrown from the buckets against the first one and then falls down and spreads upon the screen. It will then roll downward and strike another baffle door and so on, until it finally reaches the tailing spout. However, by the time it reaches this point the dust that is sufficiently ground will have passed through the screens. The doors should be bent to a slight "V" shape to spread the dust that naturally tends to follow the central channel in its course down the screen.

Drying by Storage

The advantages of clay storage and the description of a successful installation. F. H. RIDDLE. *Clayworker*, **69,** p. 32.—The very complete system installed at the Gladding McBean & Co.'s plant is described in detail in a five-page article.

Economic methods of heating clay storage sheds. CLEVE HARTZELL, Supt., Whitehall Drain Tile Co. *Clayworker*, **69,** p. 544.—In this article the author outlines a satisfactory and inexpensive system of thawing and drying frozen clays and shales.

Waste heat is taken from the kiln and circulated in 15-inch sewer pipes that are built below the floor of the storage shed.

The preparation of clays, mining, drying and proper mixing. W. W. SWENGEL. *Clayworker*, **68,** p. 235.—Often the capacity of the plant is curtailed, owing to the damp material. By the drying of the clay mechanically, a maximum output is assured throughout the entire year, where formerly the capacity was reduced in winter and wet seasons. It is important in many cases, to have a clay drier for the purpose of drying damp clay, so as to be able to eliminate pebbles and to enable the plant to make proper and exact mixtures.

The importance of clay storage. A. S. PLATT, Van Meter, Ia. *Clayworker*, **75,** p. 358.—A general discussion of the advantages of clay storage.

The storing and handling of raw clays. T. W. GARVE. *Jour. Amer. Ceram. Soc.*, **3** [4], 266.—Twenty pages of description and drawings of storage sheds and their operation.

Clay storage. H. P. ROBBINS, Adv. Mgr., Weller Mfg. Co. *Brick and Clay Rec.*, **44,** p. 1398.—Storage and conveyor systems worked out by this Company are illustrated and described. See also article by ROBBINS in *Brick and Clay Rec.*, **46,** p. 52.

Storing and weathering clay. QUES. AND ANS. *Brick and Clay Rec.*, **47,** p. 758.—NEBRASKA.—What are advantages of storage?

ANS.—Mixing, weathering, etc. Where clay contains any considerable percentage of lime, the weathering process improves it, and cases are known where the installation of a storage system with a free circulation of air through the clay has done away with a tendency toward efflorescence and has, in this way, saved the expense of using corrective chemicals.

Winter grinding and screening. ERNEST W. KNAPP, Supt., Sun Brick Co., Toronto. *Brick and Clay Rec.*, **50,** p. 635.—Economical use of storage sheds and suggestions for all year round operation.

Rotary Driers

Offers improved clay drier that costs less and saves fuel. *Clayworker*, **68,** p. 246.—Invention of W. W. SWENGEL, Bloomsburg, Pa. Three superimposed rotating cylinders, all encased in brickwork chamber. It is claimed to cost less to install and saves 30 to 40% in fuel.

New method for drying clay. *Ceramic Abstracts*, **1** [3], 85 (*Jour. Amer. Ceram. Soc.*, **5**).—Three pottery plants at Devon and Cornwall are now using a new method for drying clays in which two metal drums are employed, one enclosed in the other. The inner drum is driven by mechanical means and while revolving, steam enters in at a few degrees above the temperature of boiling water. The clay is passed into the outer drum and comes into contact with the inner drum as it revolves, filled with steam. The water in the clay is evaporated and the clay dried quickly, the process being one measured in minutes.

On the drying of raw clay. From the *British Clayworker*. (*Brick and Clay Rec.*, **54,** p. 518.) QUES.—What is the most efficient and economical way to dry from 50 to 100 tons of fresh dug plastic clay in a day of nine to ten hours?

ANS.—A cylindrical drier is preferable on account of the large amount of labor it saves. Whether the drier should be vertical and stationary or inclined and rotary depends on the nature of the clay and on its properties during the drying. A plastic clay with 16% water has been dried for 20 cents per ton. The question as to the desirability or otherwise of drying a plastic clay in order to work by a semi-dry process is a very different one; in most cases it would be unwise to endeavor to do so.

Drying plants for clay and clay products. R. GRUNHUT. *Trans. Eng. Ceram.*

Soc., **9**, p. 227.—In a rotary drier an ejector grate produces the necessary hot air and presses it through the drum, either on the counter-current principle, or, preferably, on the continuous-current method, as in the latter case the wettest clay meets the hottest air and cannot lose its plasticity owing to overheating. Rotary drums show a high degree of efficiency. Six to 9 pounds of water can be evaporated with 1 pound of coal, and one man can look after 6 and more drums. The wear is insignificant, and very little power is required to run even the largest drums. Below you will find figures giving the efficiency of a counter-current drum. Average temperature of shell and furnace not over 150°F. Material was tested for specific heat. Coal tested calorifically.

Amount of coal burned per hour	400 lbs.
Amount of moisture in coal	10%
Calorific value of coal	13,000 B.t.u.
Material dried—clayey sand	
Amount of wet material per hour	45,000 lbs.
Amount of dry material per hour	42,750 lbs.
Specific heat of material	0.21°F
Moisture in material	5%
Temperature of air and materials	60°F
Temperature of dried material	224°F

Recapitulation of computations which are given:

	%
Loss by excess temperature of material	2.5
Loss by heat in exhaust gases	6.5
Loss by imperfect combustion	0.7
Loss by radiation and other causes	4.5
Drier efficiency	85.8

Centrifugal extractors. V. Filter presses. J. W. MELLOR. *Trans. Eng. Ceram. Soc.*, **6**, p. 171.—In the hydro- or centrifugal extractor the rapid rotation of a perforated cage containing the material drives the fluid portions through the walls of the cage and leaves the solid material behind. The process works well with fibrous materials and granular substances, but not with finely divided substances. It was found that the clay slip forms a hard crust on the walls of the perforated cage. The crust is not permeable enough to permit the passage of the water from the slip in the interior of the cage.

Later: There is a recent patent for drying china clay, in which the principle of the centrifugal extractor has been applied in a very ingenious way. The clay slip runs through the center of a long cylinder with solid walls. The cylinder is rotated rapidly and solid clay collects on the walls of the cylinder, and water, free from clay, flows from the opposite end. When the exit water appears turbid the cylinder is emptied and again set to work.

Limestone—General

Carbonate of lime in clays. THE SUPT. *Brick and Clay Rec.*, **50**, p. 1055.—It comes usually in grains or small-sized pebbles, but often causes serious trouble by appearing in large-sized pebbles. Lime is a powerful flux and very sudden in action, it is exceedingly dangerous, and clays containing a large amount of it cannot be vitrified. Calcium sulphate will form if pyrites are also in the clay. Lime will tend to make a clay work and dry more easily. If a limey clay is treated with acid (which is practical only in small quantities) and the lime removed from the clay, the original red firing color will be restored. There is only one means of combating the lime menace in clays

and that is to grind the pebbles to such a small size that they are incapable of causing very much trouble. A porosity curve is also of great help in determining the best method of handling lime. If the chart shows a very abrupt drop in porosity between certain temperatures very close together, it is more than probable that lime is present and is an indication that the kiln should be held at this point until all of the gas from the lime is expelled. A quantitative test for lime may be made by boiling a sample of the clay in a diluted solution of HCl and filtering the liquid through a filter paper. Add to the clear solution thus obtained some ammonium hydroxide, which will cause a reddish precipitate. Filter off again and add to the clear hot liquid some ammonium oxalate. If lime is present, a white precipitate will result.

Limestone and "popping." THE SUPT. *Brick and Clay Rec.*, **51,** p. 499.—Clays which "pop" after firing in up- or down-draft kilns, often will not "pop" when fired in a continuous kiln, especially if the kiln has no advanced heating flue. The sulphur gases of the continuous kiln convert the lime into calcium sulphate which does not hydrate. Lime in an extremely fine condition or as a constituent of a mineral which dissociates at kiln temperatures, is extremely troublesome in the firing. It does not act as a flux at low temperatures nor until dissociation takes place and then it seems to act suddenly and completely. Some limestones, likely because they are earthy or dolomitic, do not cause "popping." Shale beds near Buffalo, N. Y. and Toronto, Canada, have interstratified streaks of limestone 6 to 12 inches thick, yet the ware made from this shale does not "pop."

The function of lime in clays. A. V. BLEININGER. *Clayworker*, **54,** p. 156.—The effect of lime carbonate in clay depends upon the composition of the lime compound and secondly upon its fineness. Some limes slake rapidly, others very slowly or not at all, an increase in magnesium content tending to decrease slaking action.

The effect of coarse lime particles in the clay after burning is too well known to need description. We know that they will swell and burst the ware as soon as water or steam from the air reaches them. It is interesting in this connection to note that if the fired clay ware is dipped into water or taken to a very moist room right after it has been taken from the kiln, while still warm, the destructive effect of the lime is very much less evident, in fact, may become insignificant. It is the practice in some European districts to lower a wheelbarrow of bricks, containing lime, into a pit filled with water as soon as it is wheeled from the kiln. The reason why lime slaked rapidly with an excess of water will not burst the ware (unless the particles are too large) is to be sought in the fact that with plenty of water at hand the quicklime will not expand as much as it does when the water absorption is more gradual.

Fine-grained lime carbonate in clay during drying acts much like sand, making such clays very easy to dry. In firing up to a certain temperature, it will cause the clay to remain porous, and if much of it is present, it will raise the heat required, considerably. As soon as a certain temperature, which depends upon the clay, has been exceeded, however, the lime becomes very active, causing the clay to vitrify and melt quite suddenly. Clays high in fine grained lime cannot be commercially fired to vitrification, as it is practically impossible to control the heat sufficiently for this purpose. An originally red firing clay by the admixture of fine lime carbonate becomes buff and, if vitrified, green.

Our clays contain frequently both coarse and fine lime at the same time and while we can eliminate the large limestone pebbles quite easily, this experiment is to determine how fine the particles smaller than the size of a pea must be crushed. He used but one red firing clay and to one-half of the bodies he added 10% of lime particles and to the other half 20%. Nine sizes of particles were added in each case, 6–8, 8–10, 10–14, 14–18, 18–20, 20–40, 40–60, 60–80, 80–100 mesh. These 18 bodies were fired to 3

different temperatures, cone 08, 06, and 04. He noted the water of plasticity in each case, also the dry, fired and total shrinkage. He concluded that more water is required to temper the mixtures, the finer the size of the crushed limestone. No significant changes are observed as regards the drying shrinkage. In all 3 of the firings, especially at the higher two temperatures, both the firing and the total shrinkage decrease as the size of the lime particles becomes smaller. The bricklets were placed in a damp closet for a week, then photographed. With 10% limestone no evident damage has resulted from the 20–40 mesh size, but with 20% the lime must be finer, 40–60 mesh. In Fig. 2 representing the same test pieces fired at a higher temperature, cone 06, we observe at once that the injury caused by the lime is not as pronounced as it was at the lower temperature. In both firings the color of the clay remained red, although it naturally was somewhat lighter than that of the clay itself. No tendency toward a buff color is observed, thus showing that the lime, in order to change the color of ferric oxide from red to a cream color, must be much finer than the sizes employed here. It seems then, that in order to assure the prevention of mechanical destruction and pitting of the fired ware, the lime particles in the raw clay must be reduced in size finer than 40 mesh. If the appearance of small specks is undesirable, it would be necessary to grind the lime finer than 60 mesh. The harder the clay is fired the coarser may the lime particles be.

As to the removal of lime from raw clay, it is evident that as much of the lime pebbles as possible should be eliminated before crushing. Following this, the clay must be ground as fine as possible. The ideal preparation would be the removal of the pebbles by means of some separating device, the drying of the clay in a rotary drier, pulverization in a disintegrator, and screening through a close sieve, after which the material would be ready for pugging.

General Discussion

RICHARD G. HOFFMAN, La Grange, Ill.—I come from a country (Germany) where they have made tremendous endeavors to get rid of lime because they cannot move, as they do in this country, to where they can get clay that is pure. They have to stay in the neighborhood of big cities and get that trade and do as best they can. We have a dozen different machines that answer fairly well the purpose of mechanically purifying clay. If the lime is in the shape of dust, or fine as flour, it is impossible to get it out, not even by washing or slumming. But if the lime happens to occur in size of grains of more than $^1/_{16}$ inch, and especially if it is in combination with a harder material, like slate, it is not so difficult to get it out, and we have had those machines constructed and in actual, practical operation for a few years which will take out lime pebbles down to about the size of a pin head and do it on a commercial scale. A ton of clay purified by mechanical process would cost from one to four or more cents a ton, according to conditions.

The behavior of granular limestone in burned clay. CHARLES F. BINNS AND MERLE A. COATS. *Trans. Amer. Ceram. Soc.*, **14,** p. 218.—BLEININGER'S work is referred to, but this work has been done quite independently of his investigation. The object of the investigation was to determine (1) the smallest size of grain at which the limestone was dangerous, (2) the amount of lime which could be present without causing harm, (3) the effect of fire in destroying the power of the lime, and (4) the possibility of treating the ware after firing so as to render the lime harmless.

An ordinary red-firing-brick clay was chosen as the body. This happened to be a surface clay of slaking character from the carboniferous horizon. Used alone it fired to a clear red and to a common brick density at about cone 01. A gray limestone used as a building stone was crushed and graded in the following sizes: 8–12, 12–20, 20–36, 36–55 mesh. Of the largest grain limestone 8–12 mesh, amounts of 1, 3, 5, and 8%,

respectively, were added to the clay. Of each mixture 9 small bricks were made by the plastic process, using a wooden mold. Three of the bricks were fired at each of the cones 06, 03, and 01 in 18 hours. The same procedure was followed in the case of the 12–20 mesh. In order to test the effect of the German practice of soaking brick containing lime, one brick of each series was immersed in water for 30 seconds and another brick was soaked to saturation immediately on being drawn from the kiln. The remaining brick of the trio was left dry. Each group of 36 bricks was then arranged in order on a shelf in the laboratory, without further treatment, and photographs taken at ten-day intervals.

There is no serious damage, at 20 days, except spalls on the surface until the 5% lime is reached. Of these the dry and dipped brick at the lower fires show signs of a weakened structure. Of the 8% series all the dry and dipped brick are crumbling, some of them being completely destroyed. The damage is rather less in the higher burn. None of the soaked brick, even with the highest content of lime, show any damage except the white spots on the surface where the lime grains are exposed. After 10 days more the spalling is worse in the members with the smaller content of lime and the disintegration of those with 5 or 8% has proceeded further. The soaked brick are still sound. Another 10 days show no change except that the disintegration which had been before noted had gone further. The soaked brick are still intact. In the series of 12–20 mesh particles practically the same phenomena are observed but in a less marked degree. It should be noted that the dipping for 30 seconds has no effect at all. Sometimes the dry brick give way first and sometimes those that were dipped.

The second series was made up with 20–36 grain limestone, percentages of 5, 8, 12, and 15 were used and 6 bricks only were set up, one at each fire being dry, the other soaked. Also a similar series with 36–55 grain limestone. After standing for 30 days no marked change could be observed. A slight disintegration shows on the edges of the 15% dry brick at cone 01, this being the first occasion in which the higher fire is less effective than the lower. A possible explanation of this is that the larger percentage of lime has produced an open and more elastic structure at the lower fire and this has served to take up the expansion of the grains. In the higher fire the body has become more resistant and, hence, it gives way under pressure. It is probable that all the 15% dry brick will eventually fail though the soaked members still appear sound. In the group containing 36–55 lime there has not yet appeared any disintegrating effect.

It appears from this study: (1) That lime grains as large as would be rejected by a 12-mesh sieve are objectionable even in small quantities, for though the brick may not be ruptured there is apt to be an unsightly spalling of the surface. (2) Lime grains which pass 20 mesh are admissible up to 3 per cent of the weight of clay, but here also there is a likelihood of surface damage. (3) That to be entirely safe the lime grains must be ground to pass a 36-mesh sieve, and that lime as fine as this may be present in a proportion as high as 12%. (4) That the danger of rupture from lime grains may be almost completely avoided by a saturation of the brick on being drawn from the kiln. This saturation appears to be more effective if the brick are in a very porous condition. Some of the members which were fired to a greater density exhibit some surface spalling, but brick were made and soaked ten months ago and are whole yet.

It has been found that a given quantity of granulated lime when wetted will expand suddenly and then shrink slightly though not to its former bulk. The same quantity of lime when exposed to the air will swell slowly though it does not reach the amount of expansion of the wetted lime.

In the experiment illustrated the same weight of freshly burned granulated lime was placed in each of two glass tubes and a dark line was marked level with the top of the lime. The tubes were set on blocks of plaster for support. Into the tube marked

"wet," sufficient distilled water was poured to thoroughly slake the lime. The tube marked "dry" was not wetted but placed in a moist atmosphere. The expansion of the wet lime was sudden and was followed by a slight shrinkage of the mass. The dry lime slowly expanded but did not reach the volume of the other. It seems as though the sudden and complete saturation of the lime caused it to deliver a quick blow, like that of a hammer, upon the surrounding clay and that after this blow, it had no further power. The dry lime on the other hand, exerts a slow and increasing pressure which under the proper conditions, is irresistible. Whether this explanation be the true one or not, it seems to present fewer difficulties than any other which has appeared.

Discussion.—PROF. BLEININGER: The authorities on lime seem to agree that the lump expansion of lime in the presence of a larger amount is smaller than in the case of a smaller volume of water. This is all I know about it, and I am very much pleased that PROF. BINNS has done this work. I have been attending for several years, the meetings of the National Lime Association and I find that they are up against the same propositions that we are with clays. Some of their evidence is, on the surface, contradictory. (Refer to BLEININGER'S paper where he states that lime on being treated with an abundance of water does not swell as much as the lime which draws the moisture from the air.)

PROF. ORTON: States instance of where pebbles that themselves were only 5% lime, caused ultimate destruction of the brick.

DR. RIES: One of his students checks results of BINNS and COATS except action was more violent.

DISCUSSION ON "EUROPEAN SILICA REFRACTORIES"[1]

M. C. BOOZE:[2] The author does not give porosity data on any of the products tested. In view of the results obtained by Harvey[3] on the resistance of silica refractories to abrasion these would have been interesting.

In the interpretation of the results which Cole obtained on the two silica cements tested, a fusion point of cone 19 for one is attributed to the fact that the sample was finely ground, 80% passing 200-mesh. It seemed hardly possible for fine grinding alone to reduce the fusion point from cone 28 which is about the average of these cements to cone 19 and to check this up a test was made using in one case a commercial silica cement 38% of which passed 200-mesh, and in the second case the same cement ground down so that it would *all* pass 200-mesh. The fusion point of the first was cone 28 and of the second, or finely ground sample, cone 26.

As far as the writer is able to judge from personal observations, there are three major differences between English and American silica brick practice.

1. In English plants the practice is followed of blending two or more types of silica-bearing rock. One of these is comparatively soft and apparently reduces more readily than the others giving the effect of grading as to grain size in the ground mud.

[1] S. S. Cole, *Jour. Amer. Ceram. Soc.*, **8** [1], 55–58 (1925).

[2] Mellon Institute, Pittsburgh, Pa.

[3] *Jour. Amer. Ceram. Soc.*, **7** [12], 895–906 (1924).

2. The grind is on the whole finer for both brick and shapes than is the practice in this country. Deep pans are used and the grinding is accomplished in from 30 minutes to $1^1/_4$ hours. Many of the plants here grind each batch in from 15 to 20 minutes. The practice of varying the grind according to the use for which they are sold is also followed in England to some extent. On open-hearth roof brick an exceptionally coarse grind has been observed.

3. Although there are at least two plants firing silica brick as hard as is customary here, this is not general. The kilns are capable of withstanding the necessary temperatures for satisfactory firing, many of them being silica lined, while in this country the side walls and crown are usually built of clay brick.

The use of fine grinds, blends of quartzites of different hardness, and the close attention which is given to the surface finish all tend to produce a density and hardness in the English product which is desirable for use in the coking chambers of by-product ovens.

While less is known of the procedure followed in Germany, at one plant which was visited there the blending of quartzites, fine grinding and soft firing which was noted at the English plants was also observed.

ACTIVITIES OF THE SOCIETY

OUR NEXT ANNUAL MEETING

The hustlers of the Southern States join the ceramists of Georgia in a hearty welcome to American ceramists to meet in Atlanta next February the week of the 8th. They have many ceramic things to show. Those who have already seen the Georgia resources

and have been favored by the southern hospitality are in great anticipation of the pleasant and instructive week the SOCIETY members and friends will have in Atlanta next February. Things unusual, things useful, things instructive and things very pleasant await us at the hands of our Georgian members.

NEW MEMBERS RECEIVED FROM FEBRUARY 21[1] TO MARCH 15

PERSONAL

Clifford L. Ach, 314 Produce Bldg., Los Angeles, Calif. Manager, Pfaltz & Bauer.
Neslon D. Booth, Superintendent, Naugatuck Valley Crucible Co., Shelton, Conn.
Albert M. Cleverley, Falkirk Iron Co. Ltd., Falkirk, Scotland.

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[1] Names of members received from Feb. 16–20 (during the Annual Meeting) appeared in the March *Bulletin*.

Wilbur C. Fisk, Logan, Ohio. President, Hocking Valley Products Co.
Charles R. Fletcher, Blasdell, N. Y. Sales Manager, The Exolon Co.
Carl H. Geister, Mellon Institute, Pittsburgh, Pa.
William A. Harty, The Exolon Co., Blasdell, N. Y. President and General Manager.
E. M. Hernandeth, 4419 Victorine St., Los Angeles, Calif. Glaze Foreman, California Clay Products Co., South Gate, Calif.
Ernest W. Huttig, New Brighton, Pa. Ceramic Engineer, Sherwood Bros. Co.
Charles C. Leigh, 6514 Van Dyke St., Tacony, Pa. Ceramic Chemist, Gillinder & Sons, Inc.
Virgil E. Ready, Los Angeles Gas & Electric Co., 810 S. Flower St., Los Angeles, Calif. Efficiency Engineer.
Oliver E. Schumacher, 717 Crenshaw Blvd., Los Angeles, Calif.
William D. Turner, 1111 State St., Rolla, Mo. Head, Department of Chemistry, University of Missouri.
Julius F. Weinhold, 48 Van Sicklen Ave., Brooklyn, N. Y. Assistant Engineer, Refractory Brickwork Dept., Alphons Custodis Chimney Const. Co., New York City.

CORPORATIONS

Cross Gas Co., Lovell, Wyo. R. E. Richardson. Vice-President.
General Motors Research Corp., Box 745, Dayton, Ohio.
Holcroft & Co., 6545 Epworth Blvd., Detroit, Mich. John T. Jans.

Membership Workers' Record

	Personal	Corporation
L. C. Hewitt	1	
B. Mifflin Hood	1	
R. B. Keeler	2	
H. J. Knollman	2	
E. Ward Tillotson	1	
Office	7	3
Total	14	3

REPORT OF THE COMMITTEE ON ENAMELING FURNACES FOR WET PROCESS CAST IRON ENAMELS

The Committee on Enameling Furnaces for Wet Process Cast Iron Enamels, in proceeding with its work, prepared a questionnaire which it was hoped would cover the main points on which information was desired for the various types of furnaces in use in this branch of the enameling industry.

Separate questionnaires on coal fired, oil fired, gas fired, and electric furnaces were made up and were sent to about fifty different enameling firms, together with a letter explaining the purpose of our gathering this information.

Twelve replies, covering fourteen different furnaces were received. The information received in these questionnaires, supplemented by somewhat less complete information supplied by *Ceramic Industry*, has been compiled in tabular form, and is presented herewith.

Furnaces D

Plant	Size of muffle	Muffle material	Fuel	Fired	Temp., °F.	Time of firing First coat	Time of firing Second coat	Heats per hour	Fuel per 24 hours	Cost per unit	Fuel cost per day	Hours operated per day	Fuel cost per operating hour	Po
A1	11½′ x 54″	Clay Flat	Coal	Direct	1600	20	12–18	2.6–3	5000	$5.70	$14.23	21½	0.663	
A2	11½′ x 54″	Carb. Flat	Coal	Direct	1600	20	12–18	2.6–3	2500	5.70	7.12	21½	.331	
B1	10′ x 42″	Clay Arch	Coal	Direct	1350 1450	15	8	3–4	1900	7.00	6.65	21½	.309	
B2	10′ x 31″	Clay Arch	Coal	Direct	1350 1450	15	8	3–4	1700	7.00	5.95	21½	.276	
C	10′ x 48″	Clay Flat	Coal	Direct	1300	10	10	3½	1350	7.04	4.75	24	.198	
D	10′ x 48″	Carb. Flat	Coal	Direct	1200 1240	10–12	10–12	4½	2000 2200	5.79	6.27	10½	.597	
E	.....	Carb.	Coal	Direct	1300	..	...	...	3000	7.50	11.25	24	.470	
F	9′ x 42″	Clay Arch	Oil	Low Press. Rockwell	1150	20	15	3–4	84 gal.	.06	5.04	24	.210	
G	9′ x 42″	Carb. "V" Bottom	Oil	Low Press. Rockwell	1300	..	...	...	168 gal.	.07	11.78	21	.560	
H	8′ x 36″ grate area 6′ x 36″	One Clay One Carb. Arch	Oil	Low Press. Wayne	1300	7–8	5–6	5	180 gal.	.0483	8.69	24	.361	
I	10′ x 54″	Carb. Flat	Oil	Low Press. Sur. Comb.	1275	8–12	8	6–8	102 gal.	.045	4.59	24	.191	
J	10′ x 48″	Clay Flat	Oil	High Press. Best	1300	7	6	8	96 gal.	.0475	4.56	24	.190	
K	9½ x 54″	Carb. "V" Bottom	Oil	Low Press. Hauck	1400	10	11–12	5–6	140 gal.	.0616	8.62	24	.359	
L	10′ x 54″	Carb.	Oil	Low Press. Sur. Comb.	1300	..	...	...	120 gal.	.062	7.44	24	.310	
M	10′ x 54″	Carb.	Oil	Low Press. Venturi	1325	7	10	...	336 gal.	.0592	20.00	24	.830	
N	10′ x 52″	Carb.	Oil	Low Press. Anthony	1300	..	...	...	172 gal.	.0638	10.95	22½	.487	
O	12′ x 66″	Carb.	Oil	Low Press.	1250	..	...	...	96 gal.	.06	5.75	24	.240	
P	10⅔′ x 42″	Carb. Arch	Natural Gas	Low Press. Sur. Comb.	1300	15	12	5	25,000 cu. ft.	1.00 per M. up to 500,000 0.60 per M. over 500,000	...	9–16	...	
Q	8′ x 48″	Ribbon Re-Resistor	Electric		1700	7–9	7–9	6–8	....	0.018 per k. w. h.	...	..	...	

ENAMELING FURNACES (Wet Process)

urnaces Data

Fuel cost per operating hour	Pounds iron fired per hour, one coat	Fuel cost per pound iron fired hourly basis	Pounds iron fired per month, one coat	Fuel cost per month	Fuel cost per pound iron fired, monthly basis	Number of men on furnace	Man hours per month	Pounds production one coat per man-hour	Type and weight of firing bars	Type of fork	Maintenance cost	Remarks
0.663	140	0.0047	70,000	$357.25	0.0051	2	1000	70	Cast Iron 200	Hand	400.00	Shut down for repairs about every six months
.331	140	.00236	70,000	178.63	.00255	2	1000	70	Cast Iron 200	Hand	None 9 months	
.309	229	.00135	120,000	126.00	.00105	2	946	128	Therm. 77	Hand Mech.	175.00	Two years' service without repairs
.276	180	.00153	70,000	115.00	.00165	2	964	74	Nichrome 30	Hand Mech.	150.00	Two years' service without repairs
.198	333	.00059	200,000	105.50	.00053	1	500	400	Therm. 75	Hand Balanced	250.00	Six months' service without repairs, old type furnaces—about to be replaced, underground flues
.597	325 475	....	80,000 133,000	180.00	....	2	586	136 222	Therm. 75 Calloy 90	Speed	150.00	One shutdown to re-level hearth One shutdown to clean flues (Both in one year)
.470	125 lbs. per load	....	....	....	....	...	...	....	....	....	100.00	
.210	340	.00062	90,000	152.00	.0008	1	600	300	Chromel 50	Hand Balanced	100.00	About two years' service without repairs
.560	577	.00097	261,000	240.00	.00092	1	453	576	Calloy "B" 60	Hand Balanced	23.13	Production and cost data is average over four months
.361	200	.00181	66,811	205.00	.00307	1	626	107	Therm. 60	Hand Balanced	100.00	Production and cost data is average over one year
.191	500 875	....	310,000 520,000	....	....	1	624	495 835	Nichrome 80	Speed	None 1st year	High production figure is on heavy coal stove castings. Low production figure is on light gas stove castings. This furnace replaced an intermittent gas fired furnace costing $0.75 per hour for fuel with only one-half the production. Two men, but no speed fork used on old furnace
.190	...	....	....	....	....	2	...	...	Therm. 80	Hand Balanced	....	
.359	...	....	99,000	260.00	.00263	2	600	165	Therm. 73	Speed	New Furnace	
.310	55 lbs. per load	....	....	....	....	.	...	...	....	....	....	
.830	725	.00114	....	....	....	.	...	...	....	....	260.00	
.487	275	.00177	....	....	....	.	...	...	....	....	None 2 years	
.240	270	.00089	....	....	....	.	...	...	....	....	None 10 months	
...	245	....	52,500	626.00	.0119	1	214	245	Chromel 42	Hand Balanced	....	
...	...	....	22,000	700.00 800.00	.0341 Basis of $750.00 per month	2	...	...	Nichrome Therm. 160	Speed	None 16 months	

Tabulation of Data

It is to be regretted that there are several quite evident inaccuracies in the table of data, but the data have been tabulated on the basis of the information supplied to the committee.

The fuel cost per operating hour has been calculated by dividing the "fuel cost per 24 hours" by the "number of operating hours per day."

Each firm submitting a questionnaire was asked for "pounds of iron fired per hour (one coat)," for "pounds of iron fired per month (one coat)," and for "fuel cost per month."

The fuel cost per pound of iron fired on the hourly basis was calculated as the quotient of the fuel cost per operating hour divided by the pounds of iron fired per hour, just as the fuel cost per pound of iron fired on the monthly basis was calculated as the quotient of the fuel cost per month divided by the pounds of iron fired per month.

The item of "man-hours per month" is the product of the number of operating hours per month and the number of men working on the furnace.

Pounds production (one coat) per man hour is the quotient of pounds of iron fired per month (one coat) divided by the man-hours per month.

All other items as given in the table are as listed in the questionnaires.

Discussion of Data

All the furnaces upon which information was obtained were used for the enameling of stove parts, but no information is given except on furnaces D and I, as to whether the work was light gas stove castings or heavy coal stove castings. On furnaces D and I, the lower value figures on pounds of iron fired are for light castings, and the larger value for heavy castings.

All furnaces with the exception of furnace D are insulated with either Sil-O-Cel or cork brick, but no information is at hand as to the amount or extent of the insulation.

Plant A reports using 5000 pounds of coal per day on a clay muffle and 2500 pounds per day on a carborundum muffle of the same size and operating at the same temperature. However it should also be noted that Plant C uses 1350 pounds of coal on a 10′ x 48″ clay muffle at 1300°F while Plant D uses over 2000 pounds on a carborundum muffle of the same size at 1200–1240°F. Of course the furnace at Plant D is not insulated, but there is a wide difference between 50% *less* coal on a carborundum muffle in Plant A and 50% *more* coal in Plant D than is used on clay muffles of the same size.

Likewise Plant M uses 336 gallons of oil per day on a 10′ x 54″ furnace at 1325°F and Plant N uses only 172 gallons of oil on a 10′ x 52″ furnace at 1300°F. However Plant M has a production of 725 pounds of enameled castings per hour, as opposed to N's 275 pounds, and operates for 24 hours instead of 22½.

Such wide divergence in data makes it extremely difficult to make any comparisons between furnaces in this report, so the data will simply be presented in the form in which it is available, with the hope that furnace men and plant engineers will themselves be able to compare to their own satisfaction the behavior of furnaces in which they are interested.

Committee

J. E. HANSEN—*Chm.*
L. A. ADAMS
L. D. BRIDGE
H. D. CUSHMAN
W. C. LINDEMANN
F. G. ROBERTS
R. D. WELLS

REPORT OF THE DIVISION COMMITTEE ON STANDARDS, 1924–1925, ENAMEL DIVISION

It seemed quite evident from the discussions which took place in connection with the report of the committee for 1923–24 that the Division was more particularly interested in the standardization of methods of control than in tests of product. Therefore the work of the year being covered was thus confined.

Unfortunately circumstances in connection with the various members of the Committees have been such that but little research work has been accomplished, and there has appeared in the literature but little that could form the basis of a study on the part of the Committee. What has been accomplished may well be considered under several headings.

Enamel Raw Materials

In view of the fact that the preliminary work of last year on clays and feldspar was done by H. C. Arnold, he was re-assigned the same duties. Early in the year he found it necessary to resign as a member of the Committee and the Chairman of the Division was unable to find another to take his place. Hence nothing is ready to report along this line.

There is being carried on by one member of the Committee a comparison of over 20 clays with reference to their relative merit in suspending enamels. This work is not yet far enough along to warrant any statements but it is hoped that the data at hand and to follow will be of value in pointing to a method of predetermining the fitness of a given clay.

Flotation of Enamels

The problem that has received more attention than any other has to do with the suspension of enamel by clay. A survey of the literature in terms of the colloid theory has been made and forms the basis of a paper on the present program. Considerable work had been done by W. N. Harrison who is at the Bureau of Standards and a progress report of his efforts is also on the program. Considerable study and some experimental work has been done along the line of the application of the conception of mobility and yield point to enamel slips. Nothing is ready for presentation, however.

Opacity of Enamel

It was suggested by the Committee of last year that the methods used for studying color and covering power of paints might have an application in connection with color and opacity of enamels. Accordingly tests with the Pfund Colorimeter are being conducted at the Bureau of Standards. Further work is to be done on the problem before a complete report can be made.

Committee
- EMERSON POSTE, *Chm.*
- R. D. COOKE
- M. E. MANSON
- W. N. HARRISON

ANNUAL REPORT OF THE REFRACTORIES DIVISION

During the year 1924 there were published in Volume 7 of the *Journal* thirty-two articles dealing with the subject of refractories and including in all 306 pages or one-third of the total volume which comprised 920 pages. Most of these articles are contributions by members of the Refractories Division.

During the year, the bibliographies on silica and magnesite were distributed in completed form. The bibliography on clay refractories was compiled in subject form without abstracts. A bibliography on chrome refractories has been started. It yet remains to prepare a bibliography on special refractories, to include the diversified materials not included in the other bibliographies.

The divisional sessions at the Columbus Meeting were longer than had ever been attempted before. In addition to the three half day sessions of the Refractories Division alone, there was also a joint symposium with the Glass Division lasting two half days and a symposium on refractories for foundry practice which lasted a half day. The latter was attended by members of the American Foundrymen's Association. This symposium was under the auspices of the United States Bureau of Mines and was the third of the series of consumers' sessions. Several papers of great value were read.

On the whole, the meeting was a success from the point of view of this Division. The program was full of interest and value; the authors were carefully chosen; and the papers well prepared. The program committee is to be congratulated for the success which crowned its efforts. The announcement board system for the simultaneous meetings was in successful operation and greatly assisted those in attendance. Some embarrassment was caused by deviating from the printed schedule. These deviations were caused by circumstances beyond the control of the officers and are to be regretted, but was the best which could be done under the circumstances. It yet remains to evolve a method to prevent speakers from overrunning their time and to make the most of the time for discussion. In view of the cost of these meetings and the expense of time and money involved to those attending, it will be seen that this is a subject deserving serious thought.

At the business sessions the following resolutions were introduced and adopted:

1. "That the Division stand in silence for one minute in memory of our late member, Raymond Miller Howe."
2. "That as far as possible, the program committee secure preprints of the papers to be presented at the next meeting."
3. "That the Division go on record as favoring the continuance of the stenographic service."
4. "That no paper be given a place on the future programs unless an abstract is submitted to the program committee."

It was moved, seconded, and voted:

1. "That the secretary be instructed to convey to the local committees and to the boys of the Ceramic School the appreciation of the Division for their services."
2. "That a vote of thanks be given to J. C. Hostetter and G. A. Bole, who so ably presided over the Symposia.

COMMITTEE REPORTS:

Standardization Committee, M. C. Booze, chairman.

A definition of magnesia brick has been written by Mr. Rochow and is being revised in view of criticism of some of the members.

Membership Committee, W. G. Owen, chairman.

Letters were written and bibliographies were distributed to prospective members and approximately twenty new members were secured through the activity of the committee. Prospect lists were made up of those who had belonged to SOCIETY and had resigned, those who attended the Meeting who were not members, and those who inquired for reprints or references from the SOCIETY publications.

Committee on Data, L. J. Trostel, chairman.

Respectfully submitted,

ROBERT F. FERGUSON,
Secretary.

LOCAL SECTION MEETINGS

St. Louis Section Meetings

On March 4, the members of the St. Louis Section met with the St. Louis Section of the American Society of Mechanical Engineers in joint dinner and business session. The subject for the evening was "Combustion and Smoke Prevention," presented by John Hunter, Consulting Engineer, and E. L. Ohle, of the Mechanical Engineering Department, Washington University.

The St. Louis Section entertained with a dinner dance at the St. Louis City Club on March 21. This was the first social gathering of the season and was greatly enjoyed and well attended by the St. Louis ceramists and their friends.

NOTES AND NEWS

OHIO STATE UNIVERSITY CERAMIC MEN HONOR PROFESSOR EDWARD ORTON, JR.

Appreciation has been expressed generally in ceramic circles for the vision, the organizing ability and the personal magnetism of Edward Orton, Jr., which made possible the establishment of the world's first collegiate department of ceramic engineering. There is no need in this note to again recite the resulting benefits which the ceramic industries have enjoyed and will continue to enjoy in increasing measure as technical ceramic research and education continue to grow in effectiveness and use. There had to be a beginning. Prof. Orton developed the mother crystal that has grown even beyond his hopes and anticipation but this growth has been vigorous because of Prof. Orton's very well prepared medium of thought development. He may have done a better job than he thought, but he did it and his doing of it is appreciated.

It is just fine that he is receiving these many expressions of appreciation while he is still vigorous in body and mind. He can the better enjoy the satisfying plaudits which are due him. The former students of Ohio State University, on the 30th Anniversary of the beginning of collegiate ceramics, desired to make a permanent record of their appreciation, a record that would in a live, vigorous fashion carry on after both Prof. Orton and those who knew him had passed beyond these earthly haunts. This testimonial of their appreciation they decided should have something of his character. They wanted their testimonial to continue serving even as the collegiate ceramic school idea which he inaugurated will continue to serve in increasing effectiveness. This they have accomplished by establishing a fellowship at the University where Professor Orton for so many years labored.

Professor Orton could have financed a fellowship in his own name. He has already built a beautiful monument to his father in the form of one of the most elegantly appointed, equipped and supplied geological libraries in America. It is exquisite in its furnishings and most complete in books relating to geology. This he has done in memory of his father, the first President of Ohio State University and one of America's foremost geologists. But to have done a similar thing for the perpetuity of his own name and in remembrance of his own works would not be to him thinkable.

Prized by him more than any of the many honors, next to the Distinguished Service War Medal, is this fellowship fund of $5000.00. In the hands of the University authorities this fund will grow until it will yield annually $600.00. This sum will be given as a prize to the ceramic student who has shown the best ability to carry on the scientific research which thirty years ago Professor Orton started. Thus will Professor

Orton's work carry on for all the years to come in his name and as a continued expression of appreciation of his pupils. It is this live expression of appreciation which Professor Orton prizes so highly. It was fitting that the Ohio State boys should have done this.

CHINESE ALUMNI MAKE UNIQUE GIFT TO OHIO STATE UNIVERSITY

An invitation was sent to each alumnus and ex-student of the Department of Ceramic Engineering of Ohio State University to return and participate in the cele-

bration ceremonies which were held on the University campus, February 16th last. A large number of the alumni and ex-students returned on this occasion and many of those who were absent sent expressions of regret.

One group of loyal ceramic engineers who were unable to attend this ceremony, made this the occasion for a beautiful gift to the Ceramic Department which gave them their education enabling them to return to their native land in which ceramics is supposed to have had its birth and to aid in the development of the art and science there. The gift is shown in the accompanying picture and the letter attached evidences the beautiful spirit which accompanies the gift.

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January 30, 1925.

Professor Arthur S. Watts,
Department of Ceramic Engineering,
Ohio State University,
Columbus, Ohio, U. S. A.

My Dear Professor Watts:

Under separate box I have sent you a portrait of Dr. Edward Orton, Jr., painted on porcelain and framed in black wood. It is a present to the Department of Ceramic Engineering from its former students, Mr. Y. Y. Wong (graduate, 1920), Mr. S. Y. Liu (ex-student), and myself (graduate, 1919), in honor of Dr. Orton, its founder, on the occasion of its Thirtieth Anniversary Celebration.

Although we did not have the pleasure of having direct contact with Dr. Orton, we want to acknowledge our great indebtedness to him for the most valuable training gotten from the Department which he conceived and founded. We, students from China, join with the ceramists of other nationalities in the recognition of his eminent services to the ceramic craft of the entire world. We sincerely regret that distance prevents us from attending the Celebration in person.

You may be interested to know that the portrait was executed by a Chinese artist, known as "Deaf Cheng." The porcelain plate was made at King-teh-cheng, Kiangse, and the frame and stand are of typically Chinese design.

We shall be very glad to hear from you about the Celebration and the progress of the Department.

With warm personal regards to you and other members of the faculty, I remain

Yours respectfully,

Chi Chun Lin

Address: 242 Avenue Haig, Shanghai, China.

BUREAU OF STANDARDS NOTES

Cast Iron for Enameling Purposes

Enamels for bath tubs, stove parts, and other cast iron wares often blister during the firing process, causing loss to the manufacturer and increased cost of the perfect product to the consumer.

The Bureau of Standards, in coöperation with the AMERICAN CERAMIC SOCIETY, has undertaken a thorough study of cast iron for enameling purposes with a view to determining the iron most suitable for this work, and, if possible, the cause of blistering of the enamel when fused onto castings made from certain types of pig iron. Two types of pig iron are being used in the cupola charge. It is a popular opinion among enamelers that castings made from 100% pig iron of these two types cause blistering of the enamel, while this condition is remedied somewhat by adding scrap castings to the melt. In each of the first two experimental runs of castings, 100% of the above mentioned pig iron was employed.

Sample castings were enameled both in the laboratory and in the plants of various manufacturers. The enamels used are designated by the trade as the wet and dry process enamels. The wet process enamel is ground fine and suspended in water as a slip, using clay as the floating agent. This slip is sprayed onto the casting, dried and fused at comparatively high temperatures. The dry process enamel is also fused at these temperatures, but the casting is first heated and the dry enamel powder sifted on to give a smooth coat.

The results of the enameling of the first runs of castings have been checked. It was found that blistering occurred in the enamel on all castings except those on which the single coat wet process enamel was fused at comparatively low temperatures. The blisters appeared as pinholes in the enamel and as dimples on the surface where the enamel was too thick or viscous to allow the bubbles to "blow" through. The highest temperature at which no blistering occurred was 1290°F. Above this temperature unsatisfactory results were obtained. No conclusions have been drawn, since the investigation is not far enough advanced. Further work has been planned to include varying cupola charges from which castings are to be enameled, both in the laboratory and in commercial plants. Chemical, metallographic, and spectroscopic analyses will be made of the castings before and after enameling in order to determine any changes which might take place, due to the enameling process. This report covers the results obtained with 75 castings. It is estimated that a similar number will be used from each cupola run.

Standardization of Seger Cones

The work started by the Bureau some months ago in connection with the standardization of Seger cones is making satisfactory progress.

A preliminary report on this subject was presented before the AMERICAN CERAMIC SOCIETY at the Columbus meeting on February 18th. The number of papers on the program prevented formal discussion of the report, but informal conversations with representative members of the SOCIETY assured the Bureau of the interest being taken in the work, and the general approval of the methods being followed.

Plastic Refractories

Clay refractories, furnished to the trade in their plastic form, are rapidly supplanting special shapes in boiler settings and similar installations. The demand for this material for repair work is also rapidly increasing, so that at the present time it has been estimated that the total daily output exceeds 100 tons. Because of the increasing importance of this commodity to the trade, and the fact that the Government is contemplating the formation of specifications for its purchase, the Bureau of Standards undertook to determine the physical and chemical characteristics of several commercial brands of these plastic refractories.

Test specimens, made by hand-ramming in molds, were fired, subjected to standard and modified tests for fire clay refractories, and also analyzed chemically and petrographically. The information obtained indicates that plastic refractories as now furnished to the trade are inherently the equivalent of the highest grade fire clay brick.

A comparison of softening point determinations and chemical analyses by three independent laboratories shows that a variation of from one-half to one cone in softening point determinations, and more than 5% on some constituents in chemical analysis, can be expected for different samples representing one brand or product.

BUREAU OF MINES NOTES

Graduate Fellowships Offered

Graduate fellowships in mining, metallurgical and chemical research are offered by prominent institutions of learning in various states, in coöperation with the Bureau of Mines of the Department of the Interior. The object in offering these fellowships is to assist in the solution of different problems being studied by the Bureau of Mines that are of particular importance to the region in which these institutions are located. The fellowships offer excellent opportunities for qualified young men to become proficient in the fields of mining, metallurgical and chemical technology, and to prepare themselves for highly specialized work in these fields.

The following-named institutions offer such fellowships for the college year, 1925–1926:

University of Alabama, Tuscaloosa, Ala., 5 Fellowships, $540 each.
University of Arizona, Tucson, Ariz., 2 Fellowships, $660 each.
Carnegie Institute of Technology, Pittsburgh, Pa., 4 Fellowships $750 each.
University of Missouri, Rolla, Mo., 4 Fellowships $800 each.
Ohio State University, Columbus, Ohio, 3 Fellowships, $750 each.
University of Utah, Salt Lake City, Utah, 5 Fellowships, $750 each.
University of Washington, Seattle, Wash., 5 Fellowships, $750 each.
University of Idaho, Moscow, Idaho, $750 each.

Detailed information in regard to the terms of these various fellowships may be obtained from the Department of the Interior, Bureau of Mines, Washington, D. C., or from the different institutions named.

SOCIETY OF GLASS TECHNOLOGY MEETING

A meeting of the Society of Glass Technology was held in the Applied Science Department, the University, St. George's Square, Sheffield, Wednesday, Feb. 18, the President, S. C. Halse, in the chair.

The meeting was devoted to a consideration of the use of sillimanite in the glass industry, two papers being presented. Within the last two years, very large deposits of sillimanite have been discovered in India and these deposits are now being worked by a British firm, Pawle and Brelick of London, and all the experiments described were conducted with material from this source.

The first paper was entitled "A Study of Sillimanite for the Purpose of Preparation of Refractory Materials," by A. Cousen and W. E. S. Turner.

The authors observed that recent developments in the glass industry had emphasized the need for good refractory materials, and although much has been done to

improve and render more uniform the fire clays now employed, it was of importance to examine other material likely to give better results. The authors had made a study of sillimanite, and the effect of variation of grain size and of the use of varying types and proportions of bonding agent were dealt with. The most plastic mixtures, and those giving on fire clay the most stable and resistant pots were obtained by using sillimanite wholly or largely in the fine condition in which the bulk of the material passed through a 100-mesh sieve. With ball clay as a bonding material good results were found when a proportion of 15 to 30% of bond was employed. The porosity of hand molded specimens was inversely proportional to the amount of bonding agent used and with the addition of 30% of ball clay reached as low as 22%. Actual melting tests with soda-lime, potash, lead and fluoride opal batches gave glasses superior in color to, and having a lower iron oxide content than those melted in good fire clay pots. Test slabs both with 15 and 30% of bond withstood a larger breaking load than fire clay slabs after firing at 1000 to 1400°, but after heating to 100° or 800° the clay slabs gave superior results. Stourbridge clay gave a less plastic mixture which gave on firing to 1400° a more porous texture than equivalent mixtures in which ball clay was used. The Stourbridge clay mixtures, however, gave promise of producing quite good results when molded into shape under pressure. Bentonite, a hydrated silicate of aluminium of variable composition, although giving the most plastic mixtures proved unsatisfactory in practice, and the results obtained did not justify its employment as a bonding agent.

The second paper was entitled "Some Notes on the Use of Sillimanite as a Glass Works Refractory," by F. G. Clark and W. J. Rees. The authors explained that for many years manufacturers have been looking for a refractory material which would not only stand the higher temperatures at which in recent years furnaces had been worked, but also withstand the action of melting batch and molten glass upon it at that high temperature. Tests under commercial conditions showed that molten glass had very little attack on articles made of sillimanite and should have very little effect on sieges made of this material. Brick of various sizes and thicknesses had also been made of a sillimanite mixture and used for filling up the exit flues of furnaces when they had worn too big. It was found that these brick stood the heat perfectly. The mixture was also used in a damp state for repairing the bad places between the pillars and springers in an old furnace, with excellent results. The best results had been obtained with sillimanite bonded with from 10 to 25% of ball clay. A covered pot had been made from 25% ball clay mixture soaked for 4 weeks before use. This pot was 43 inches high and took 13 days to make. Its cost was greater than that of the ordinary fire clay pot, but longer life in the furnace and freedom from pot stones would compensate for this. The material was also recommended for rings floating in the glass and for bottoms of tank furnaces. Its thermal conductivity was higher than that of fire clay. The authors expressed the opinion that sillimanite was the best refractory material yet known for use in the hottest part of any glass furnace, either in contact, or out of contact, with glass.

Two other papers were communicated but not read, namely.

(*a*) "The Early Glasshouses of Bristol," by Francis Buckley.

(*b*) "Sur la Viscosite et l'Allotropie du Verre," by Prof. Henry Le Chatelier.

NEWS FROM THE UNIVERSITY OF ILLINOIS

Mr. Douglas F. Stevens of the Acme Brick Company, Danville, Illinois, addressed the students in Ceramic Engineering, University of Illinois, Friday, March 13, on

the operation of the new system of firing which has recently been installed in their plant.

The Illinois Gas Association has recently presented to the University of Illinois several gas furnaces of different types. The Department of Ceramic Engineering received as its share of the gift, a volcano surface combustion fusion furnace, a testing furnace requiring the use of gas under pressure and capable of reaching temperatures of 3200 to 3300° F. Also, a special surface combustion furnace for firing ceramic wares under high temperature conditions.

Mr. A. V. Bleininger of the Homer-Laughlin China Company, Newell, W. Va., delivered three lectures to the students of the Department of Ceramic Engineering, University of Illinois, on March 18 and 19. The topics of his addresses were: (1) The work of ceramist; (2) The operation of tunnel kilns; (3) Research in factory practice.

CALENDAR OF CONVENTIONS

Organization	Date	Place
Am. Assn. of Flint and Lime Glass Mfrs.		
(Annual Meeting)	July, 1925	Atlantic City, N. J.
AMERICAN CERAMIC SOCIETY		
(Annual Meeting)	Feb. 8–13, 1926	Atlanta, Ga.
(Summer Meeting)	July, 1925	Toronto, Canada
(Fall Meeting)	Oct. 1, 1925	New York City
Am. Electrochemical Soc.		
(Spring Meeting)	April 23–25, 1925	Niagara Falls, N. Y.
(Fall Meeting)	Sept. 24–26, 1925	Chattanooga, Tenn.
Am. Engineering Council	Jan., 1926	
Am. Foundrymen's Assn.	Oct. 5–9, 1925	Syracuse, N. Y.
Am. Gas Assn.	Oct. 12–16, 1925	Atlantic City, N. J.
Am. Inst. of Chem. Engrs.	June 22–25, 1925	Providence, R. I.
	July 13–16, 1925	Leeds, England
Am. Inst. of Min. and Met. Engrs.	Aug. 31–Sept. 5	Salt Lake City, Utah
Am. Iron and Steel Inst.	May 22, 1925	New York, N. Y.
Am. Mining Congress	May 25–29, 1925	Cincinnati, O.
Am. Soc. of Mechanical Engrs.		
(Spring Meeting)	May 18–21, 1925	Milwaukee, Wis.
(Annual Meeting)	Nov. 30–Dec. 3	New York City
(Pacific Coast Regional Meeting)	June 22–25, 1925	Portland, Ore.
Am. Soc. for Testing Materials	June 22–26, 1925	Atlantic City, N. J.
Assn. of Scientific Apparatus Makers	April 23–25, 1925	Washington, D. C.
Baltimore-Washington Section		
(AMERICAN CERAMIC SOCIETY)	April 4, 1925	Washington, D. C.
Brussels International and Commercial Fair	March 25–April 8	Brussels, Belgium
Chemical Equipment Exposition	June 22–27, 1925	Providence, R. I.
Common Brick Manufacturers Assn.	Feb., 1926.	
Eastern Clay Products Assn.	April 14, 1925	Pittsburgh, Pa.
Glass Container Assn.	April 30–May 2	Atlantic City, N. J.
Institution of Chemical Engineers	July 13–16, 1925	Leeds, England
Manufacturing Chemists' Assn.	June, 1925	New York City

Mining and Met. Society of America	Jan. 12, 1925	New York City
Natl. Academy of Sciences	April 27–29, 1925	Washington, D. C.
Natl. Assn. of Mfrs.	Oct. 26–28, 1925	St. Louis, Mo.
Natl. Assn. of Stove Mfrs.	May 13–14, 1925	New York City
Natl. Chemical Equipment Assn.	June 22–27, 1925	Providence, R. I.
Natl. Clay Products Industries Assn.	April, 1925	Chicago, Ill.
Natl. Lime Assn.	May 26–29, 1925	Briarcliff Manor, N. Y.
Natl. Exposition of Chem. Industries	Sept. 28–Oct. 3, 1925	New York City
Soc. of Chem. Industry	July 13–16, 1925	Leeds, England

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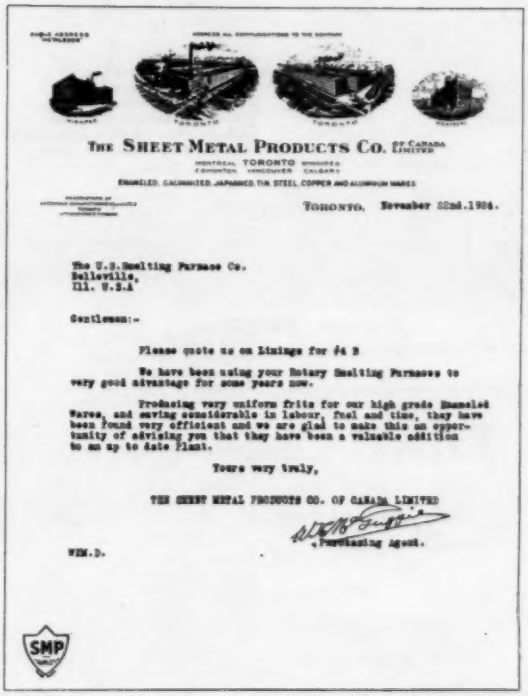

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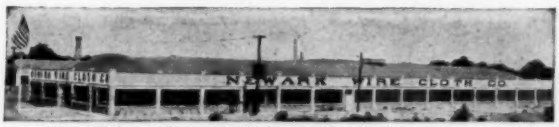

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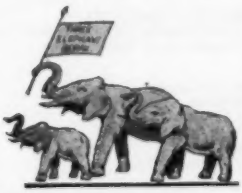

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ATLANTA, the 1926 Convention City.

Central of Georgia Railway

J. M. MALLORY
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Thus, a thorough study of available factory space in relation to equipment to be installed, is necessary to insure the best possible results.

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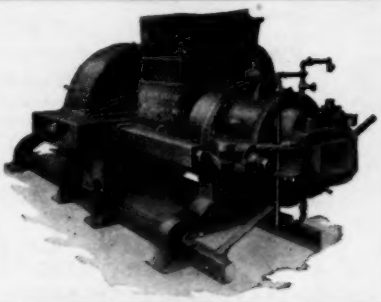

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A fineness of 98% passing 48 mesh, or 80% passing 200 (or coarser) can be secured with the Rotary Classifier. Where a finer product is required, the combined Rotary and Superfine Classifier is used, as a double classification feature in this makes it possible to meet the most severe specifications regarding fineness. These Classifiers have been operating on ceramic materials, limestone and shale for rock dusting, coal for pulverized coal units, etc. Capacities range from 400 pounds to 35 tons an hour for the Rotary and 300 pounds to 23 tons an hour for the Superfine.

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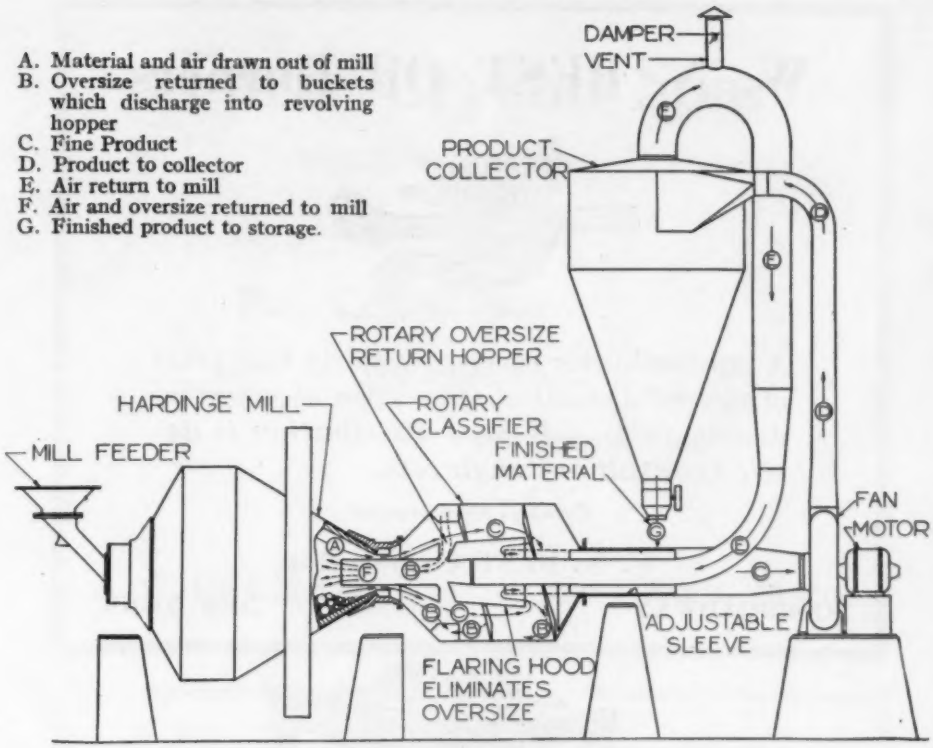
B. Oversize returned to buckets which discharge into revolving hopper
C. Fine Product
D. Product to collector
E. Air return to mill
F. Air and oversize returned to mill
G. Finished product to storage.



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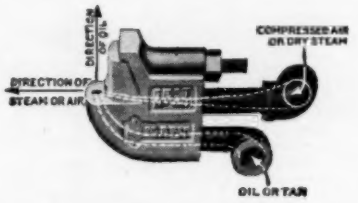

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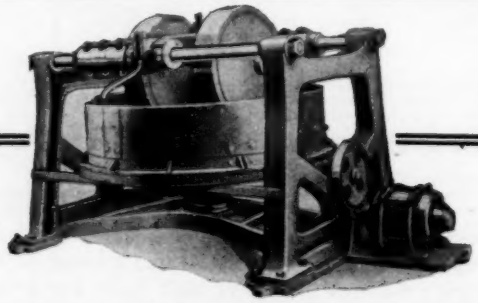
11 BROADWAY **NEW YORK**



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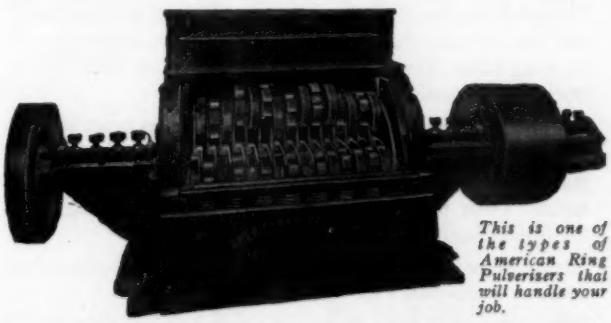

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See how the ring method of crushing brings lower operating cost and an elimination of costly shut-downs.

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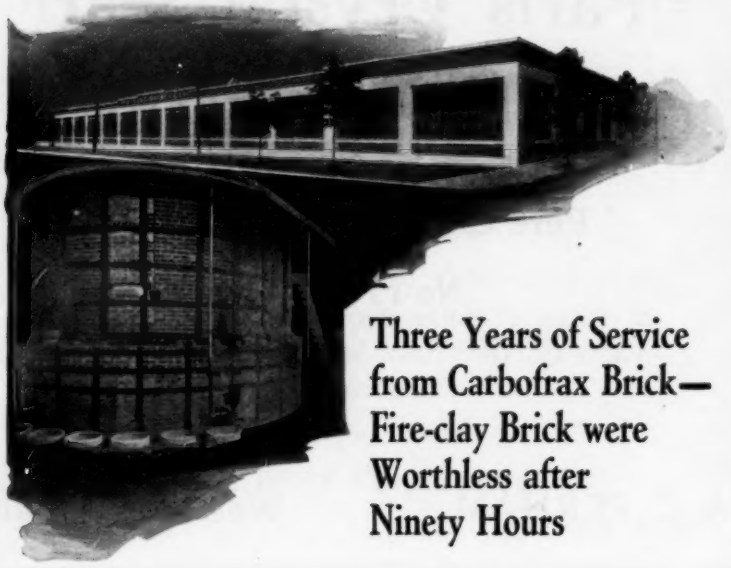

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The best grade of fire-clay brick lasted but two heats of from forty-two to forty-five hours each.

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Brick and Tile for Boiler and Furnace Settings; Muffles for Enameling Furnaces; Hearths for Heat-Treating Furnaces; Cements for all High Temperature Work

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G-E Direct-Heat Units radiate quick, clean heat direct to the charge—electric heat so uniformly distributed throughout the furnace, and so accurately controlled that the maximum speed and highest quality of vitreous enamel are obtained.

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